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Summary of Catalyst Performance Measured during the Aftermarket Catalyst Durability Evaluation Project

(U.S.) Environmental Protection Agency
Ann Arbor, MI

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16. ABSTRACT

This report describes engine-out and tailpipe exhaust emission performance done on 23 aftermarket catalysts. The study was based upon modal data collection, i,e, collecting emission data during each of the 23 discrete idle-to-stop modes of the Federal test procedure (FTP) driving cycle.

17. KEY WORDS AND DOCUMENT ANALYSIS

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Technical Report

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by

J. P. Cheng
M. L. Alff
K. H. Hellman

April 1986

NOTICE

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Background

The figures in this report show the engine-out and tailpipe emission performance for the testing done in the aftermarket catalyst program. The details of that program can be found in the report, "Durability Evaluation of Aftermarket Catalysts," EPA/AA/CTAB/86-01, March 1986. These analyses were made possible by modal data collection, i.e., collecting emission data during each of the 23 discrete idle-to-stop modes of the FTP driving cycle.

Individual Test Results

Most of the figures show the data from a given catalyst at a given mileage point. The engine-out emissions are plotted as cumulative percent total emissions, and begin at zero and end at 100 percent. The x-axis is normalized distance during the test, again from zero to 100 percent. When the test is done (100 percent of the distance has been accumulated) the engine has produced all of the emissions on the test (100 percent). The tailpipe emissions are normalized to the engine-out total, so that when the test is over, the total normalized tailpipe emissions are not 100 percent because the catalyst acts to reduce the tailpipe emissions, compared to the engine-out emissions.

Each plot involving percent distance has two tic marks on the x-axis, one between 30 and 40 percent and the other between 60 and 70 percent. The first tic mark shows the end of Bag 1 of the emission test, and the second tic mark shows the end of Bag 2 of the test.

Data from each catalyst is coded numerically and located in the report as shown:

Code	Manufacturer	Pages
#1 (1-1)	Walker	4 through 28
#2 (1-2)	Walker	
#3 (1-3)	Walker	
#4 (2-1)	Echlin	29 through 50
#5 (2-2)	Echlin	
#6 (2-3)	Echlin	
#7 (3-1)	Brown	51 through 76
#8 (3-2)	Brown	
#9 (3-3)	Brown	

On each figure, six numerical measures of catalyst performance are listed. Three of these measures are "efficiency" values, and three are "time" values.

In order for a catalytic emission control system to be effective, the catalyst must quickly become active in reducing emissions and when it is active, it must have high conversion efficiency.

Efficiency Measures

The three efficiency measures are "FTP efficiency," "overall efficiency," and "hot efficiency." All are expressed in percent.

FTP efficiency values are computed by using the individual analysis results to simulate a three-bag FTP test, with the weighting factors applied, for both engine-out and tailpipe emissions.

Hot efficiency is determined by using only the portion of the test where the catalyst is fully warmed-up. For the purposes of this report the modes that are used to compute this value are those that corespond to Bag 2 of the FTP test. Hot efficiency is greater than FTP efficiency for HC, typically by 5 or 6 percent. Hot effiency can be compared to the values of stabilized efficiency determined by engine dynamometer testing of catalysts.

Overall efficiency is a value that is based on the cumulative emissions during the test. Since the tailpipe emissions are normalized to the total engine-out emissions, the value of tailpipe emissions at the end of the test (at percent distance = 100 percent) are less than 100 percent. In fact, the overall efficiency is just 100 percent minus the cumulative normalized tailpipe emissions at percent distance = 100 percent. The overall efficiency value is directly relatible to the grams of tailpipe emissions and is not affected by FTP weighting factors. Overall efficiency is usually close to, but about 1 percent lower than, FTP efficiency.

Time Measures

The three time values used are called "10 percent T," "T50*," and "50 percent T." All are expressed in seconds.

The value 10 percent T is determined as follows. When the cumulative emissions put out by the engine have been reduced by 10 percent, the catalyst is just beginning to become active. The "engine-out" and the "tailpipe-out" curves on the figures are just beginning to separate.

The value 50 percent T is calculated in the same way and represents the time at which 50 percent of the emissions have been converted. Of course, if a catalyst never reaches an overall efficiency of 50 percent, the 50 percent T time is undefined.

The value T50* is based on a different approach than the other two time values. The value of T50* is a measure of instananeous conversion efficiency as opposed to cumulative conversion efficiency. T50* is the time at which the catalyst is first operating at 50 percent efficiency; whereas, 50 percent T is the time at which 50 percent of the cumulative emissions emitted during the test have been converted. In general, 10 percent T is the smallest value, and 50 percent T is the largest of the three time parameters.

These three light-off parameters are expressed as times rather than distances, because measures of catalyst light-off measured on engine dynamometer tests are typically expressed in units of time, and the objective in this was to develop a parameter which could be compared to engine dynamometer results. T50* is the time parameter that most closely corresponds to light-off time as measured on engine dynamometer tests.

Summary Figures

Following the figures that describe catalyst performance at each test, summary figures by catalyst manufacturer are presented. These summary figures show the efficiency and light-off time performance of the catalysts versus mileage.

The performance deterioration of the catalysts shows up in two ways: 1) efficiency values get lower with accumulated mileage, and 2) light-off times get longer with accumulated mileage. In addition, those catalysts which showed deterioration substantially different from the others of the same type are easily identified.

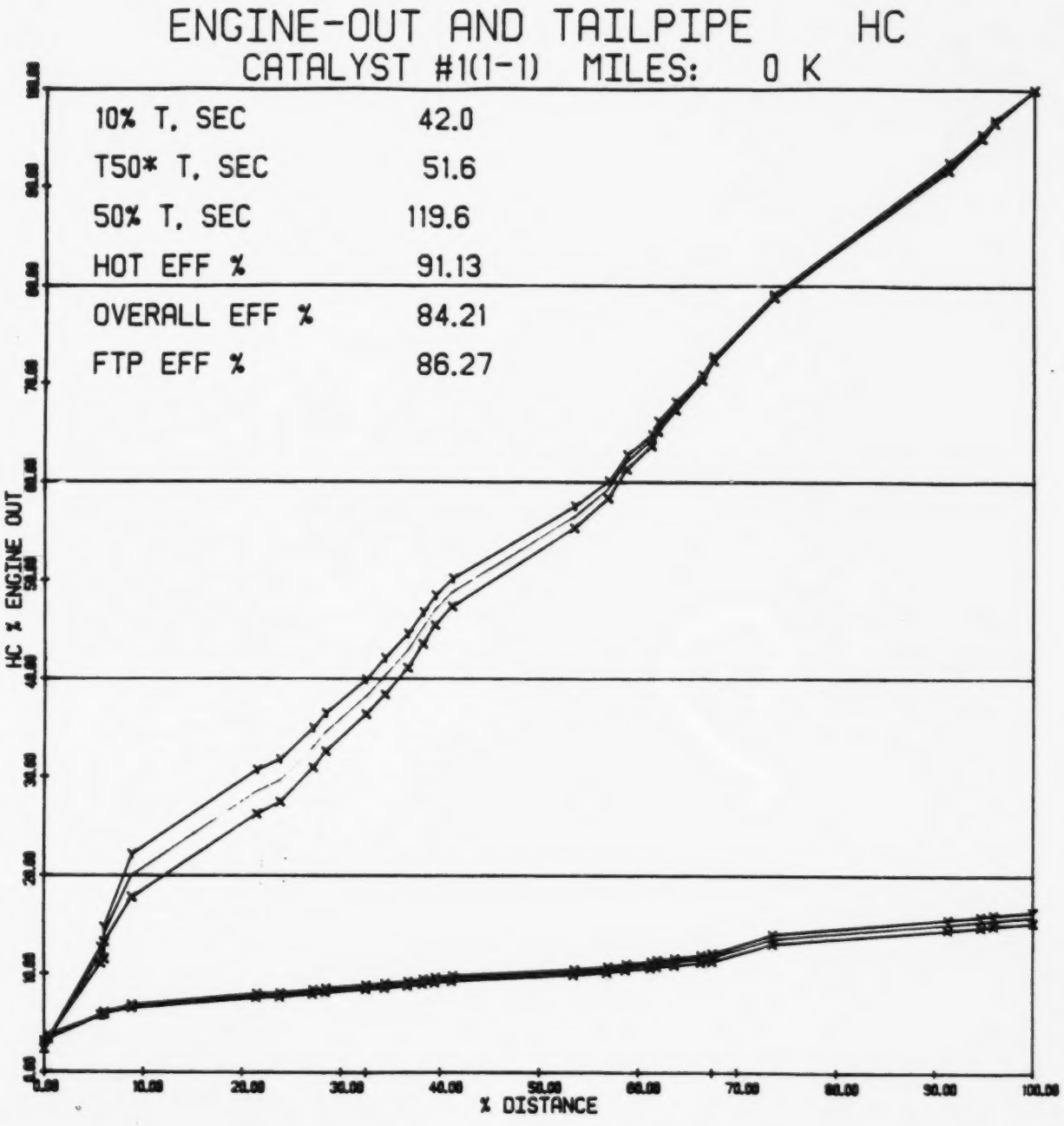
Engine-Out Data

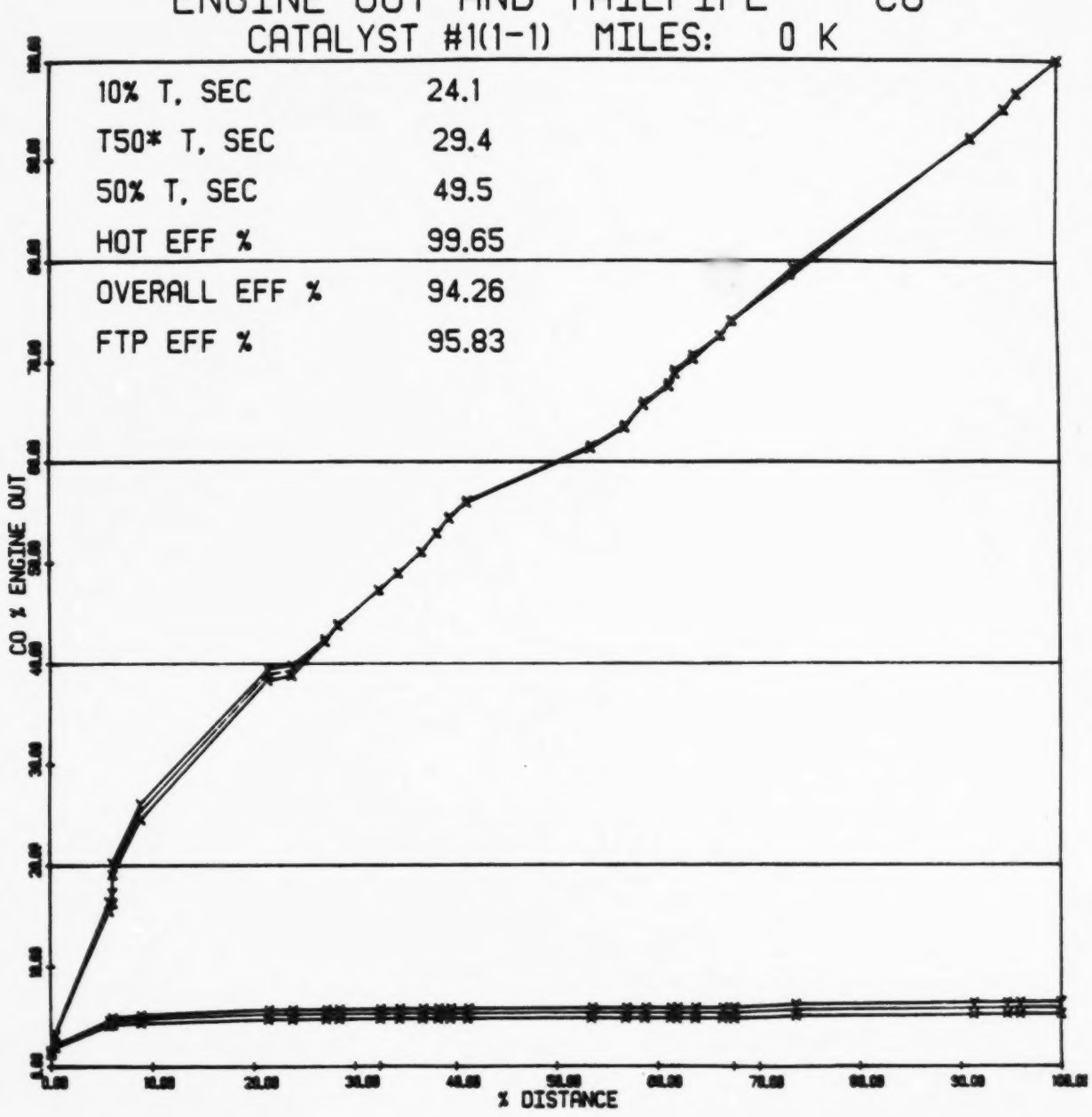
Plots summarizing the engine-out HC and CO performance of he test vehicle used to evaluate the catalysts show average and a erage ± one standard deviation of cumulative emissions during th test. The emission values are not normalized for these two fig res, but are shown as grams. The test vehicle is seen to emit about 30 ± 3 grams of HC and about 570 ± 40 grams of CO durin the test.

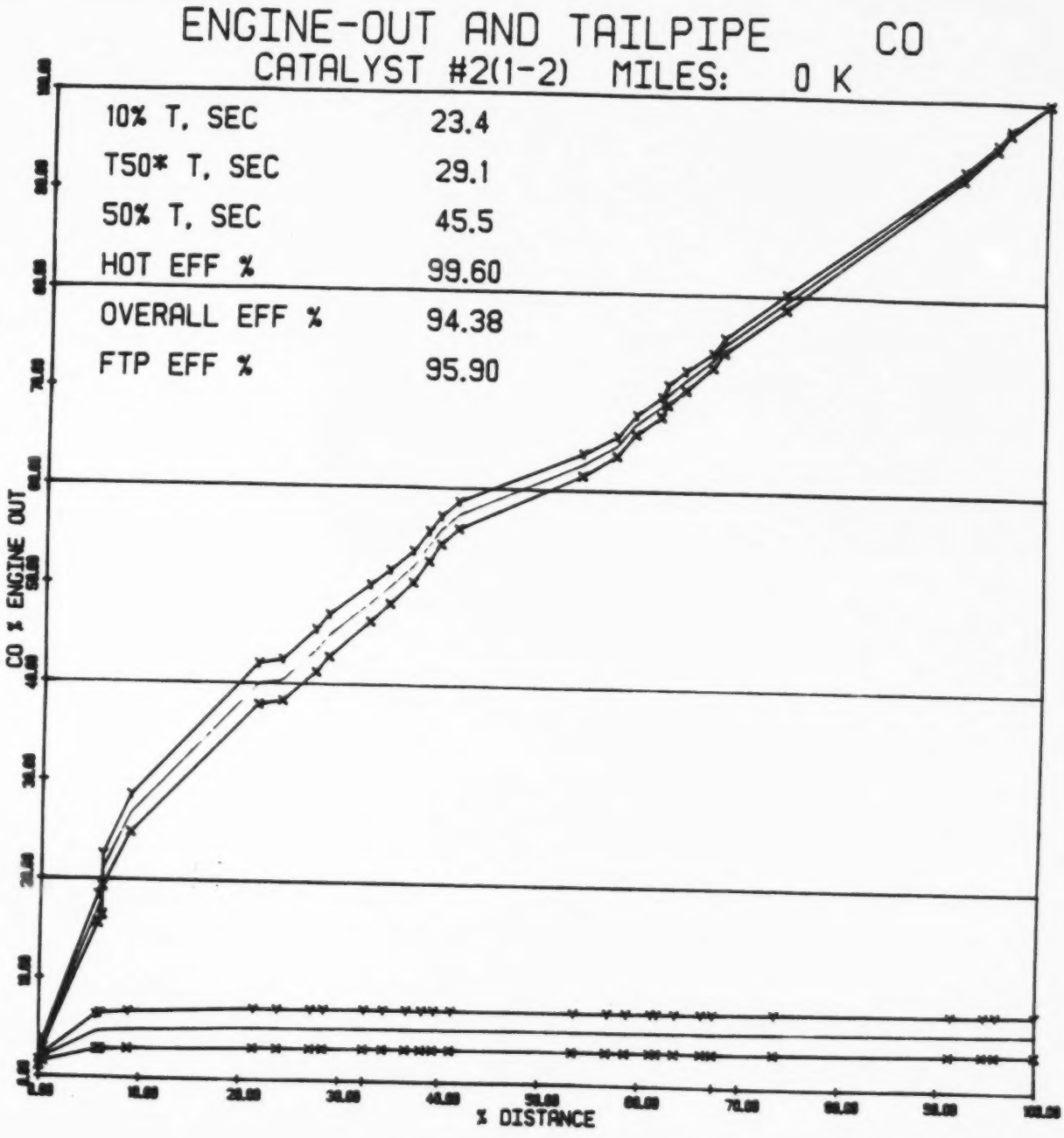
Tabular Data

Numerical values of the catalyst performance values are listed in the tables of data that comprise the final portion of this report.

Walker Catalyst Data


ENGINE-OUT AND TAILPIPE HC
CATALYST #1(1-1) MILES: 0 K
10% T, SEC 42.0
T50* T, SEC 51.6
50% T, SEC 119.6
HOT EFF % 91.13
OVERALL EFF % 84.21
FTP EFF % 86.27
HC % ENGINE OUT
% DISTANCE


ENGINE-OUT AND TAILPIPE CO
CATALYST #1(1-1) MILES: 0 K
10% T, SEC 24.1
T50* T, SEC 29.4
50% T, SEC 49.5
HOT EFF % 99.65
OVERALL EFF % 94.26
FTP EFF % 95.83
CO % ENGINE OUT
% DISTANCE



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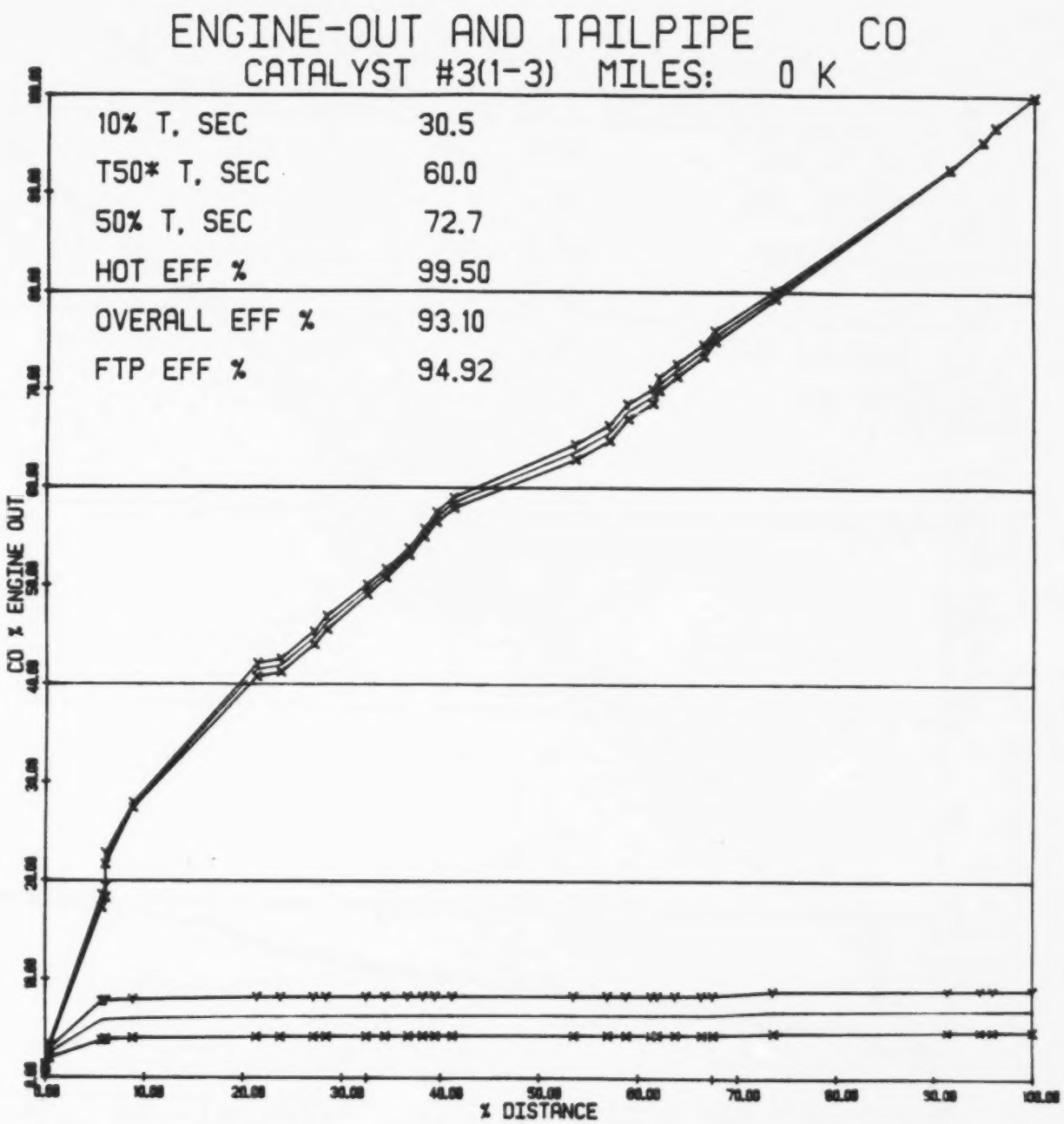

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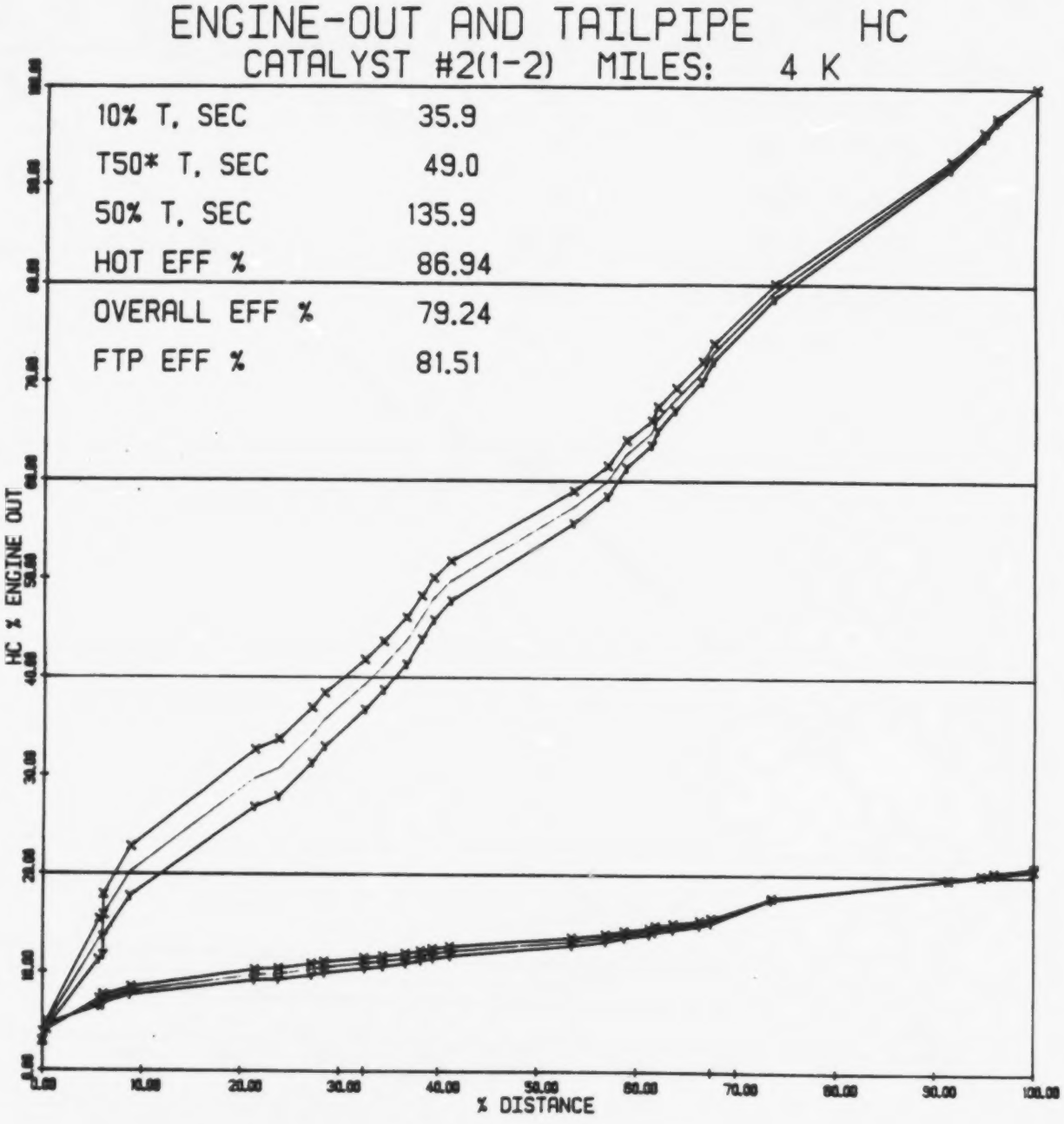
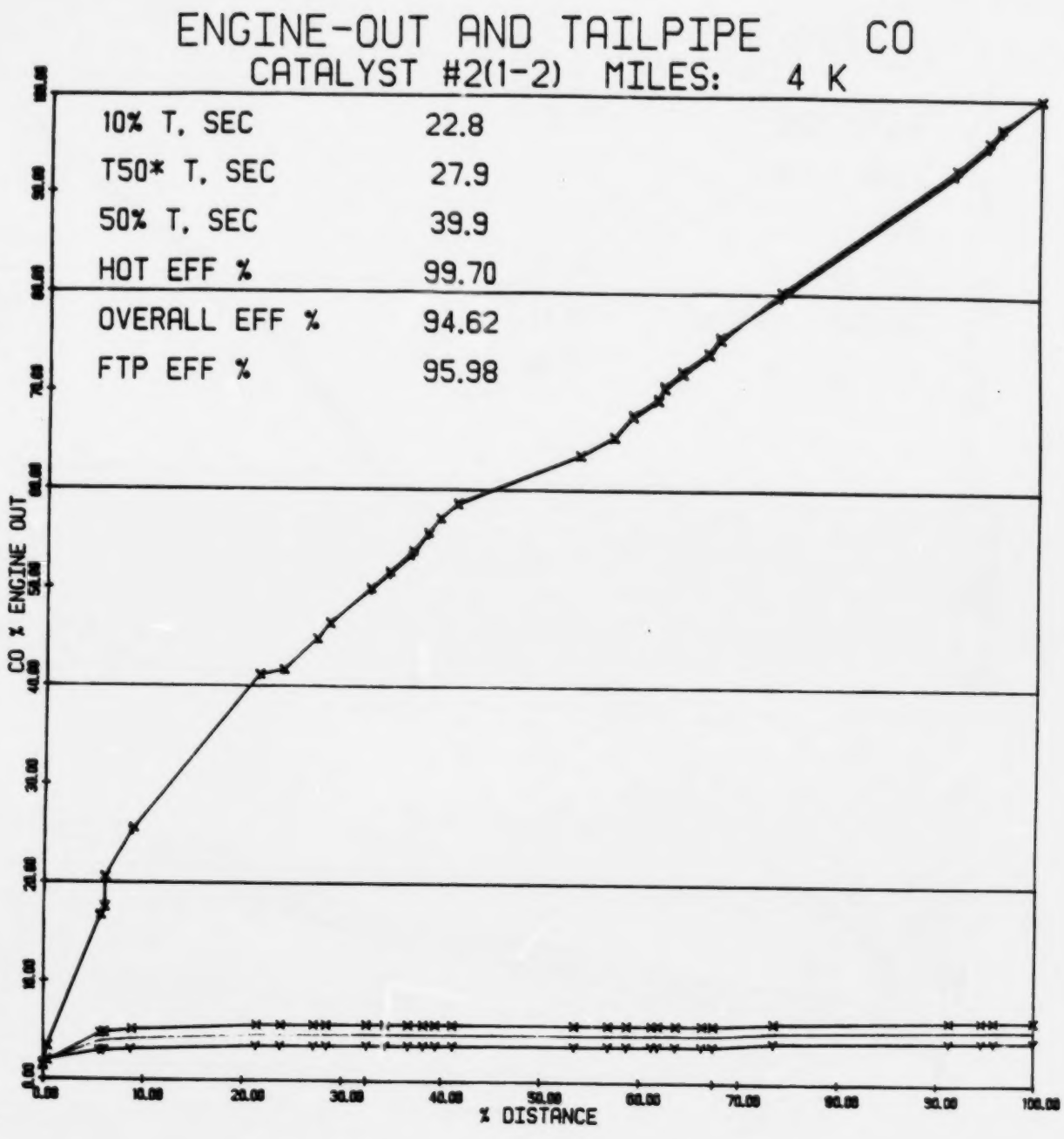
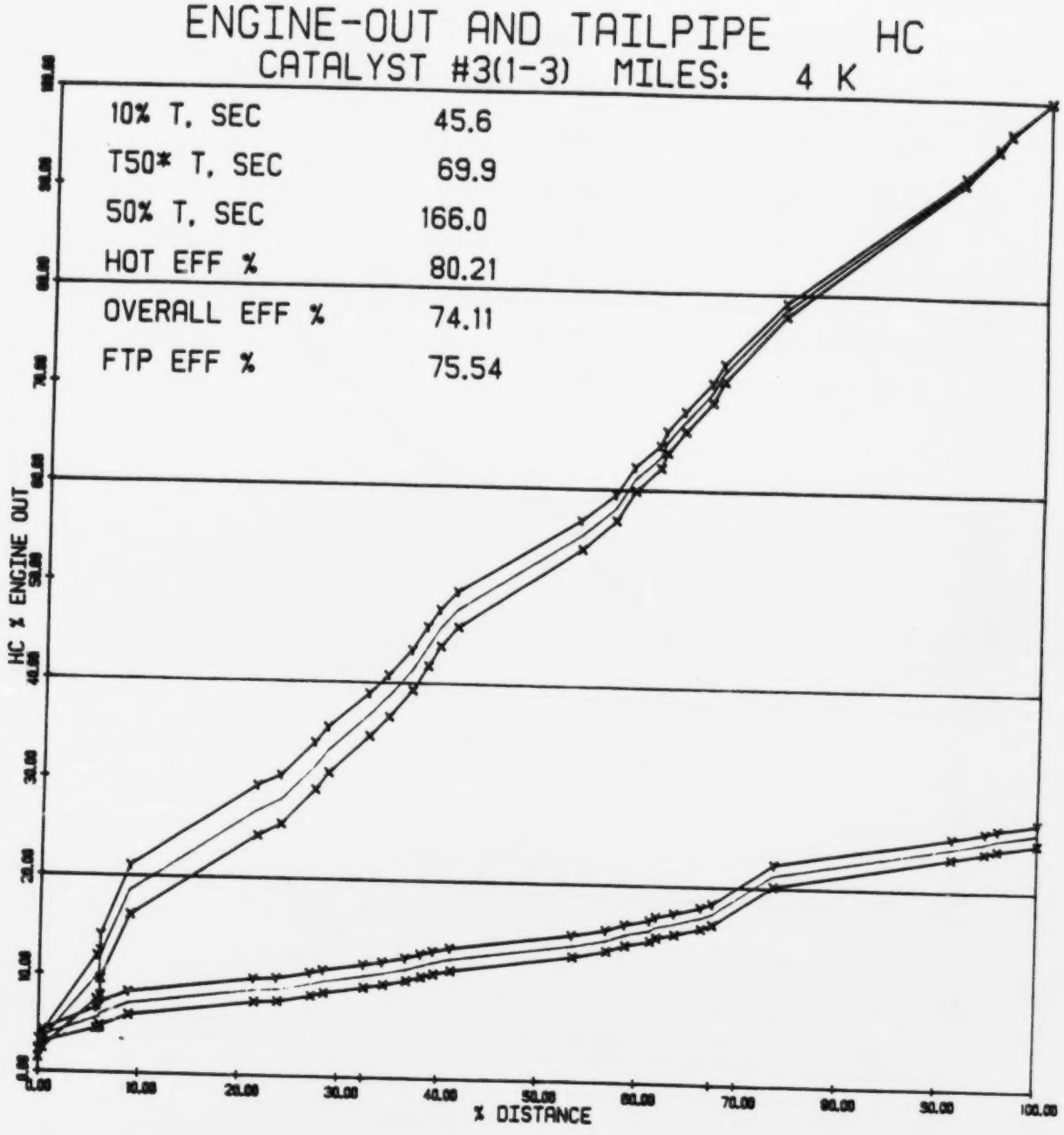
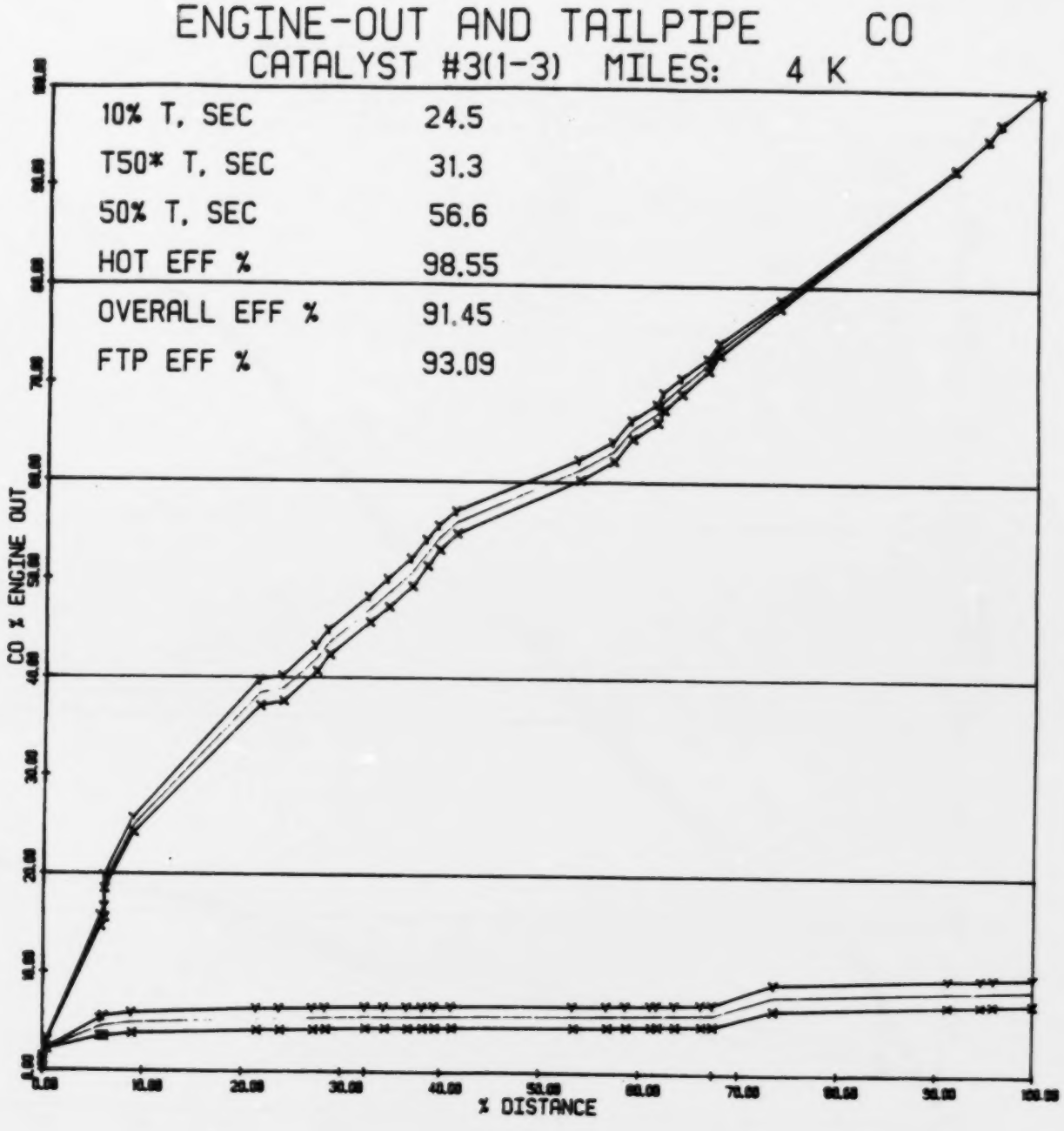
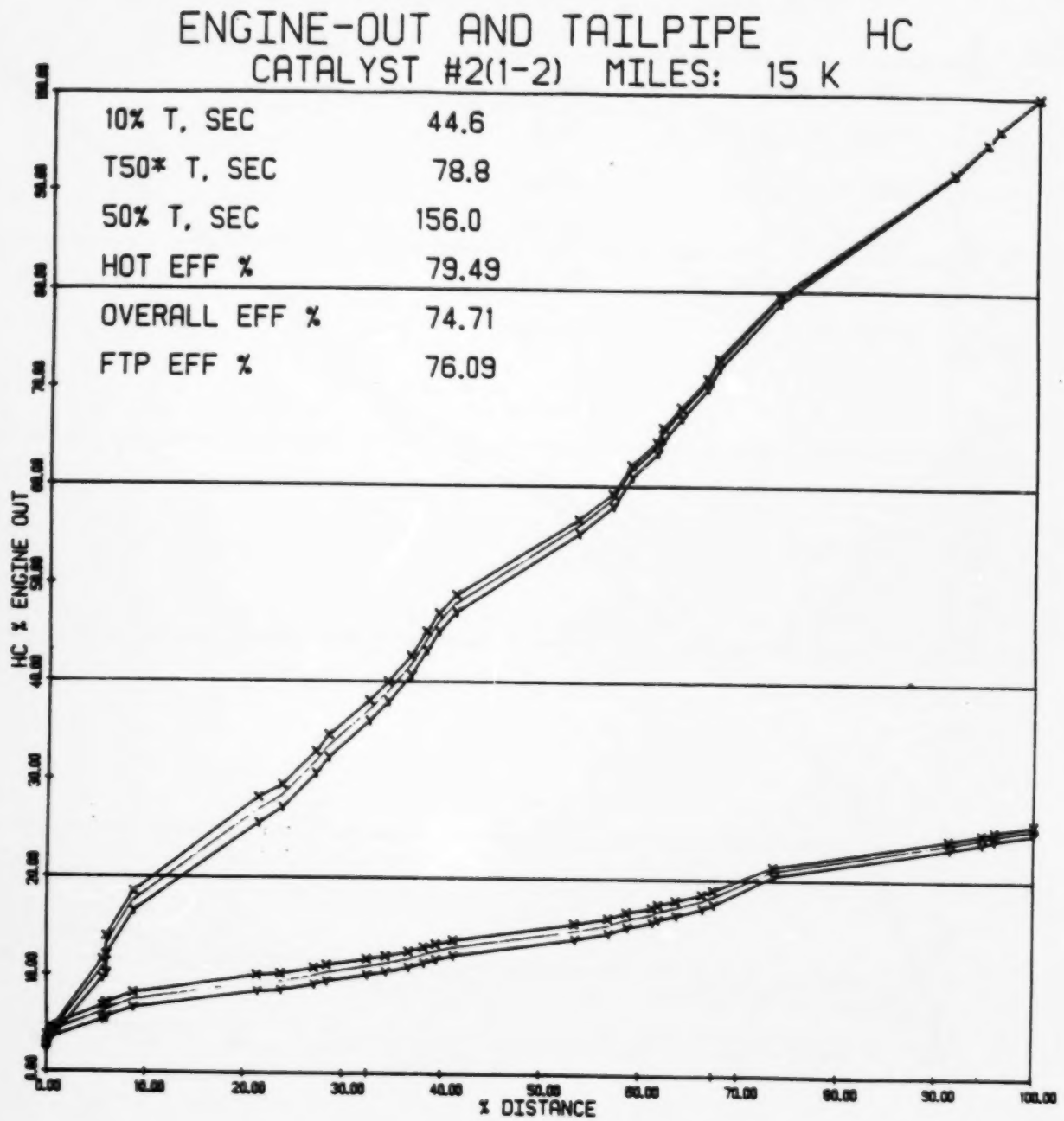

ENGINE-OUT AND TAILPIPE HC
CATALYST #2(1-2) MILES: 4 K
10% T, SEC 35.9
T50* T, SEC 49.0
50% T, SEC 135.9
HOT EFF % 86.94
OVERALL EFF % 79.24
FTP EFF % 81.51
HC % ENGINE OUT
% DISTANCE


ENGINE-OUT AND TAILPIPE CO
CATALYST #2(1-2) MILES: 4 K
10% T, SEC 22.8
T50* T, SEC 27.9
50% T, SEC 39.9
HOT EFF % 99.70
OVERALL EFF % 94.62
FTP EFF % 95.98
CO % ENGINE OUT
% DISTANCE


ENGINE-OUT AND TAILPIPE HC
CATALYST #3(1-3) MILES: 4 K
10% T. SEC 45.6
T50* T. SEC 69.9
50% T. SEC 166.0
HOT EFF % 80.21
OVERALL EFF % 74.11
FTP EFF % 75.54
HC % ENGINE OUT
% DISTANCE


ENGINE-OUT AND TAILPIPE CO
CATALYST #3(1-3) MILES: 4 K
10% T, SEC 24.5
T50* T, SEC 31.3
50% T, SEC 56.6
HOT EFF % 98.55
OVERALL EFF % 91.45
FTP EFF % 93.09
CO % ENGINE OUT
% DISTANCE


ENGINE-OUT AND TAILPIPE HC
CATALYST #2(1-2) MILES: 15 K
10% T, SEC 44.6
T50* T, SEC 78.8
50% T, SEC 156.0
HOT EFF % 79.49
OVERALL EFF % 74.71
FTP EFF % 76.09
HC % ENGINE OUT
% DISTANCE
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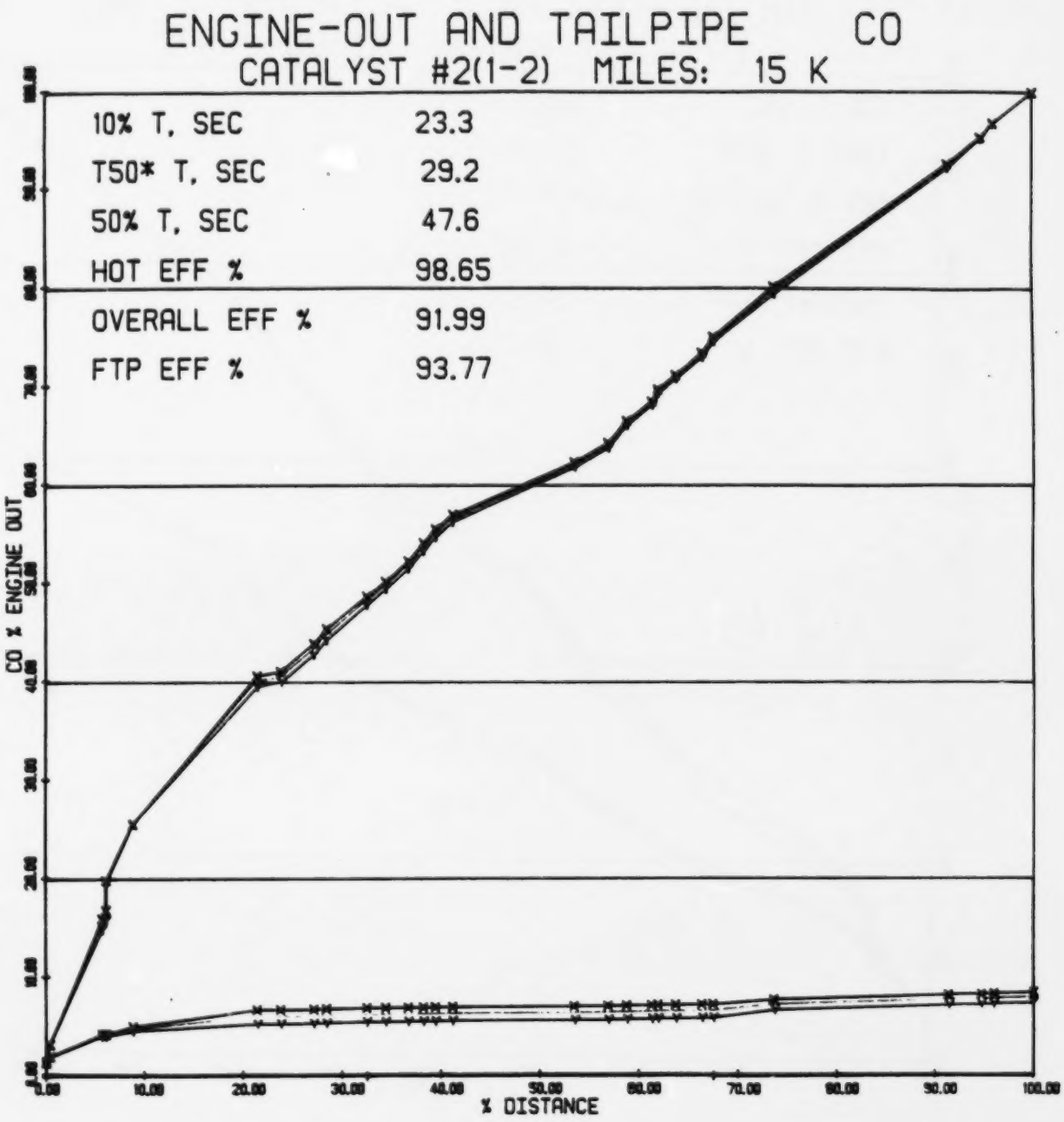
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00


ENGINE-OUT AND TAILPIPE CO
CATALYST #2(1-2) MILES: 15 K
10% T, SEC 23.3
T50* T, SEC 29.2
50% T, SEC 47.6
HOT EFF % 98.65
OVERALL EFF % 91.99
FTP EFF % 93.77
CO % ENGINE OUT
% DISTANCE
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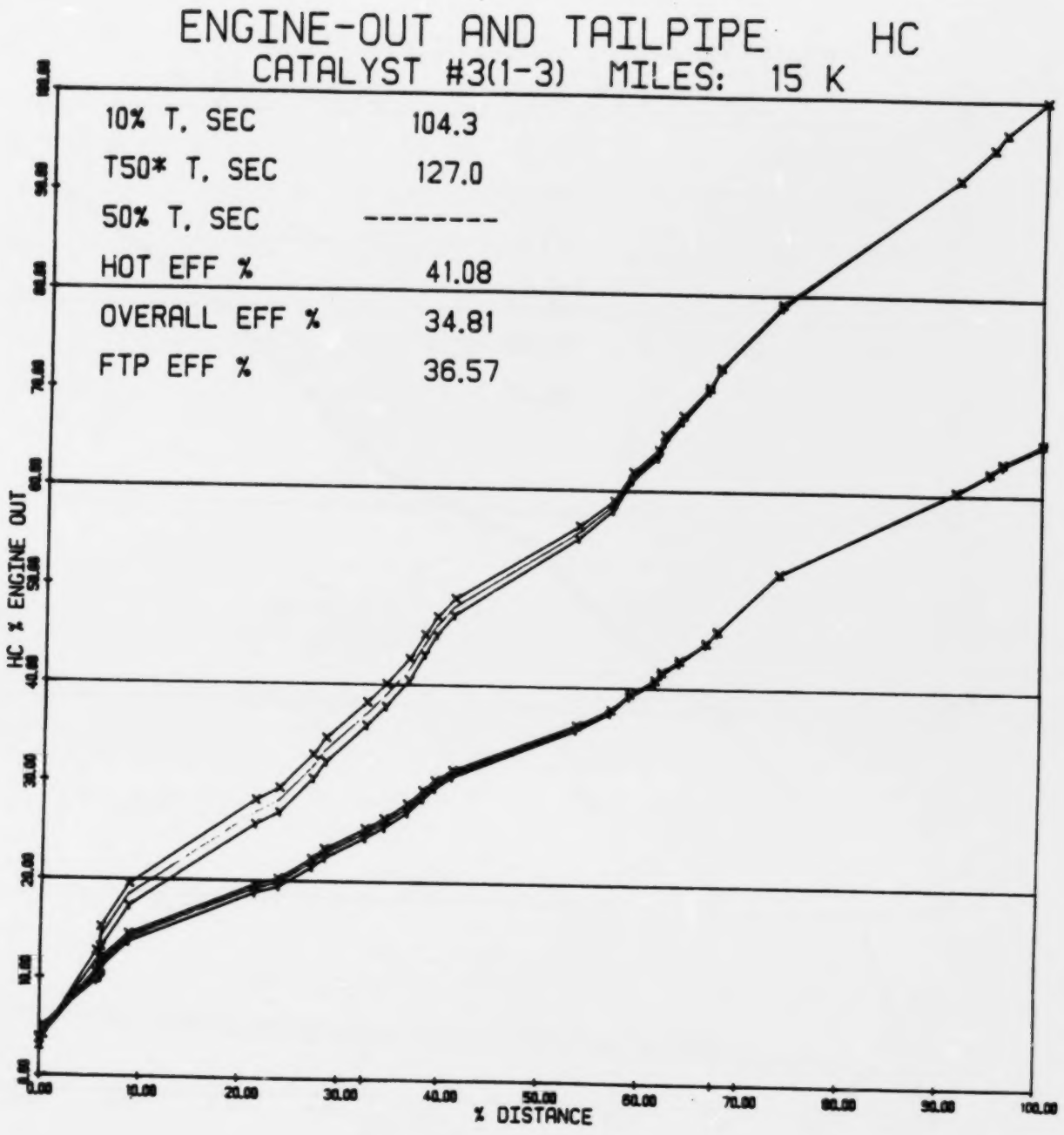
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00


ENGINE-OUT AND TAILPIPE HC
CATALYST #3(1-3) MILES: 15 K
10% T, SEC 104.3
T50* T, SEC 127.0
50% T, SEC --------
HOT EFF % 41.08
OVERALL EFF % 34.81
FTP EFF % 36.57
HC % ENGINE OUT
% DISTANCE
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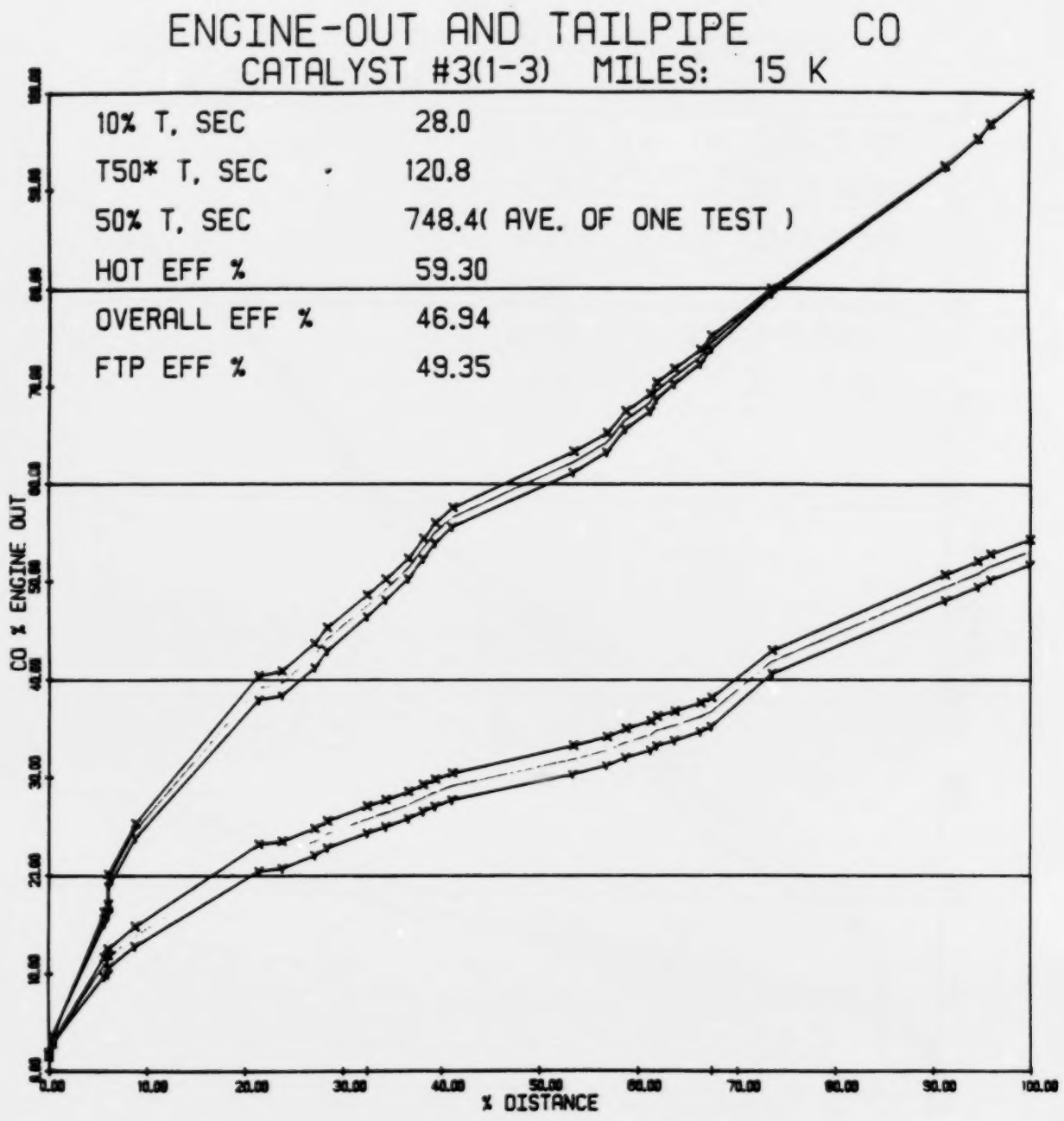
ENGINE-OUT AND TAILPIPE CO
CATALYST #3(1-3) MILES: 15 K
10% T, SEC 28.0
T50* T, SEC 120.8
50% T, SEC 748.4(AVE. OF ONE TEST)
HOT EFF % 59.30
OVERALL EFF % 46.94
FTP EFF % 49.35
CO % ENGINE OUT
% DISTANCE
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10.00
20.00
30.00
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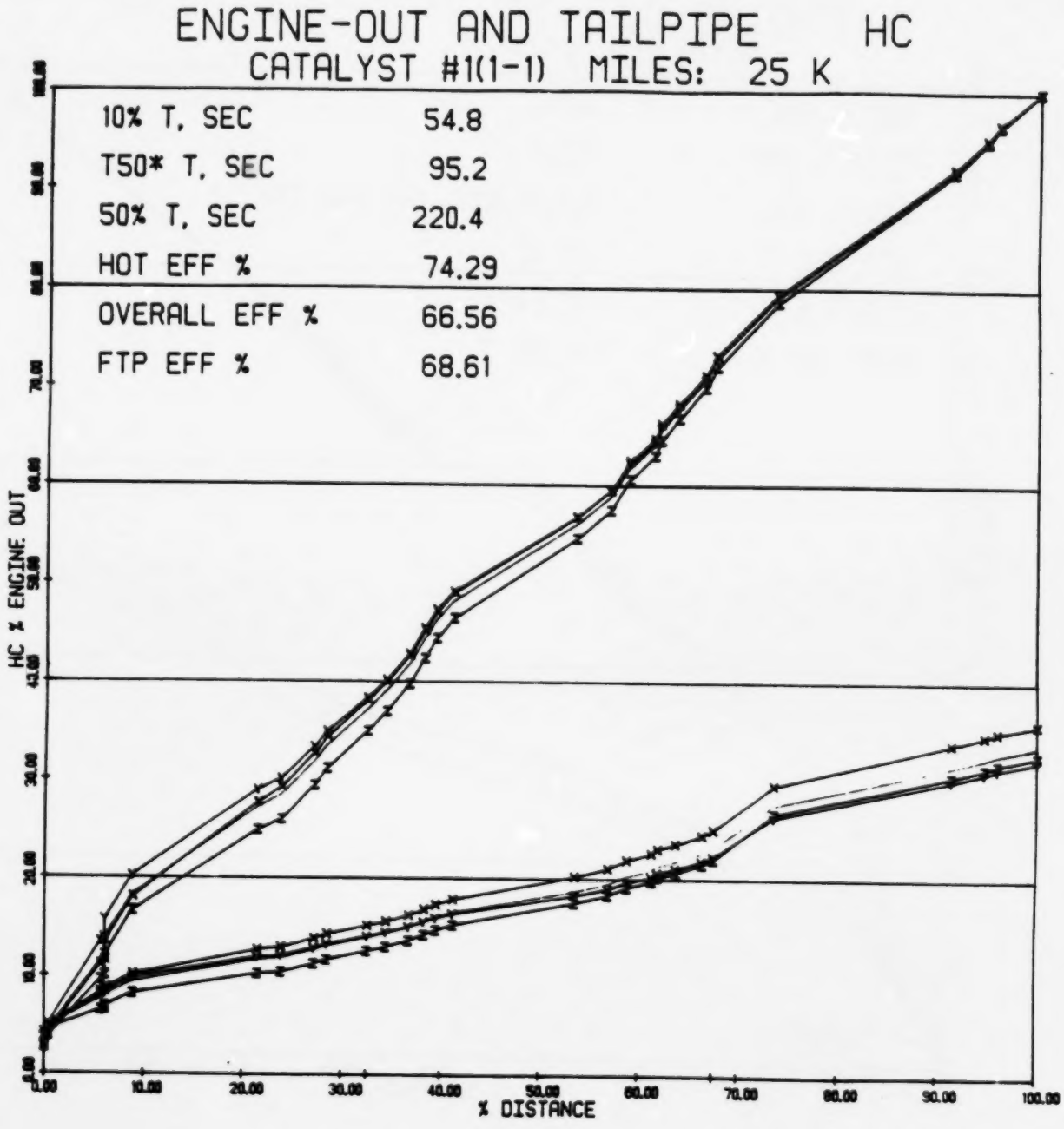
50.00
60.00
70.00
80.00
90.00
100.00


ENGINE-OUT AND TAILPIPE HC
CATALYST #1(1-1) MILES: 25 K
10% T, SEC 54.8
T50* T, SEC 95.2
50% T, SEC 220.4
HOT EFF % 74.29
OVERALL EFF % 66.56
FTP EFF % 68.61
HC % ENGINE OUT
% DISTANCE
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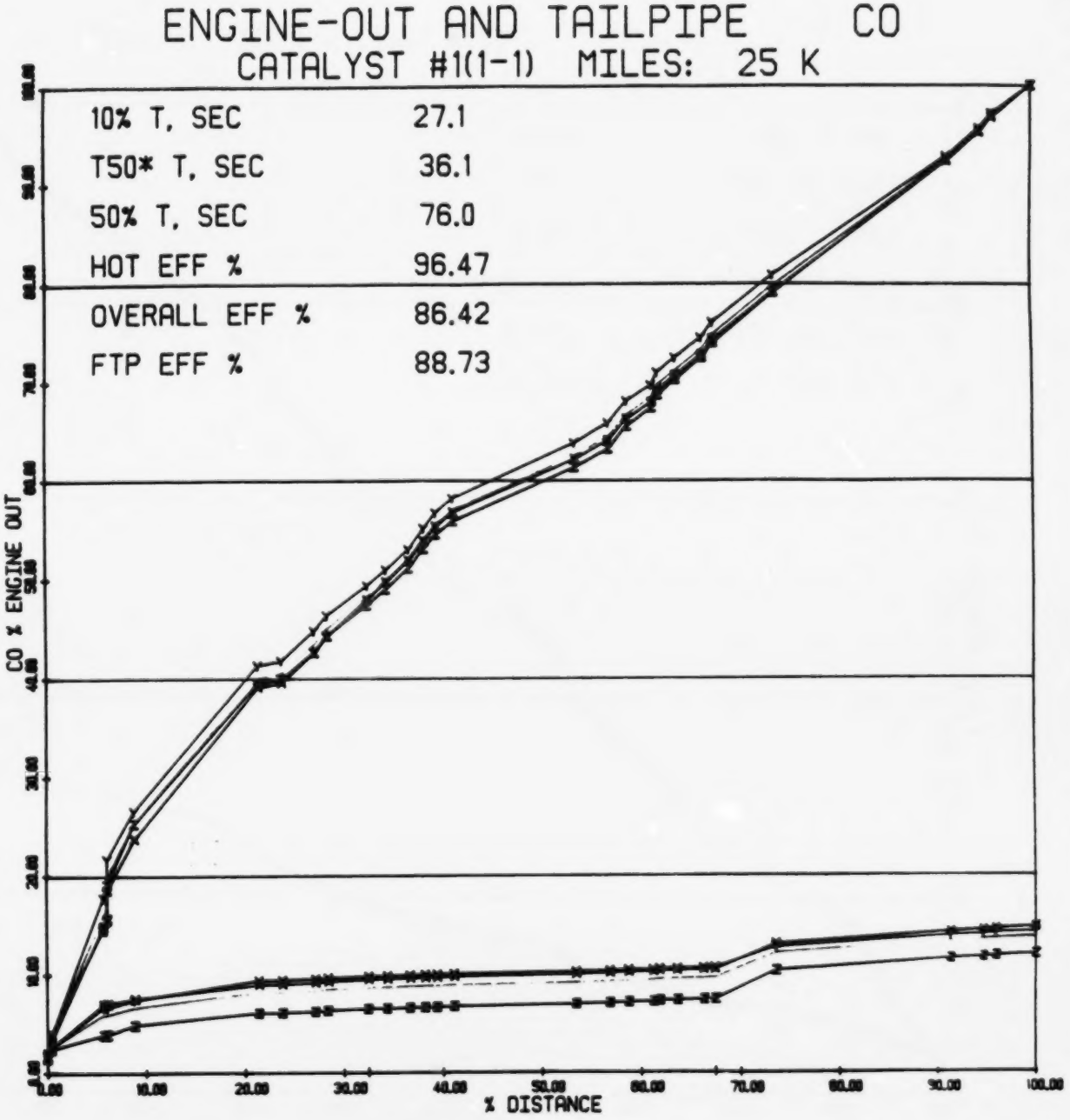
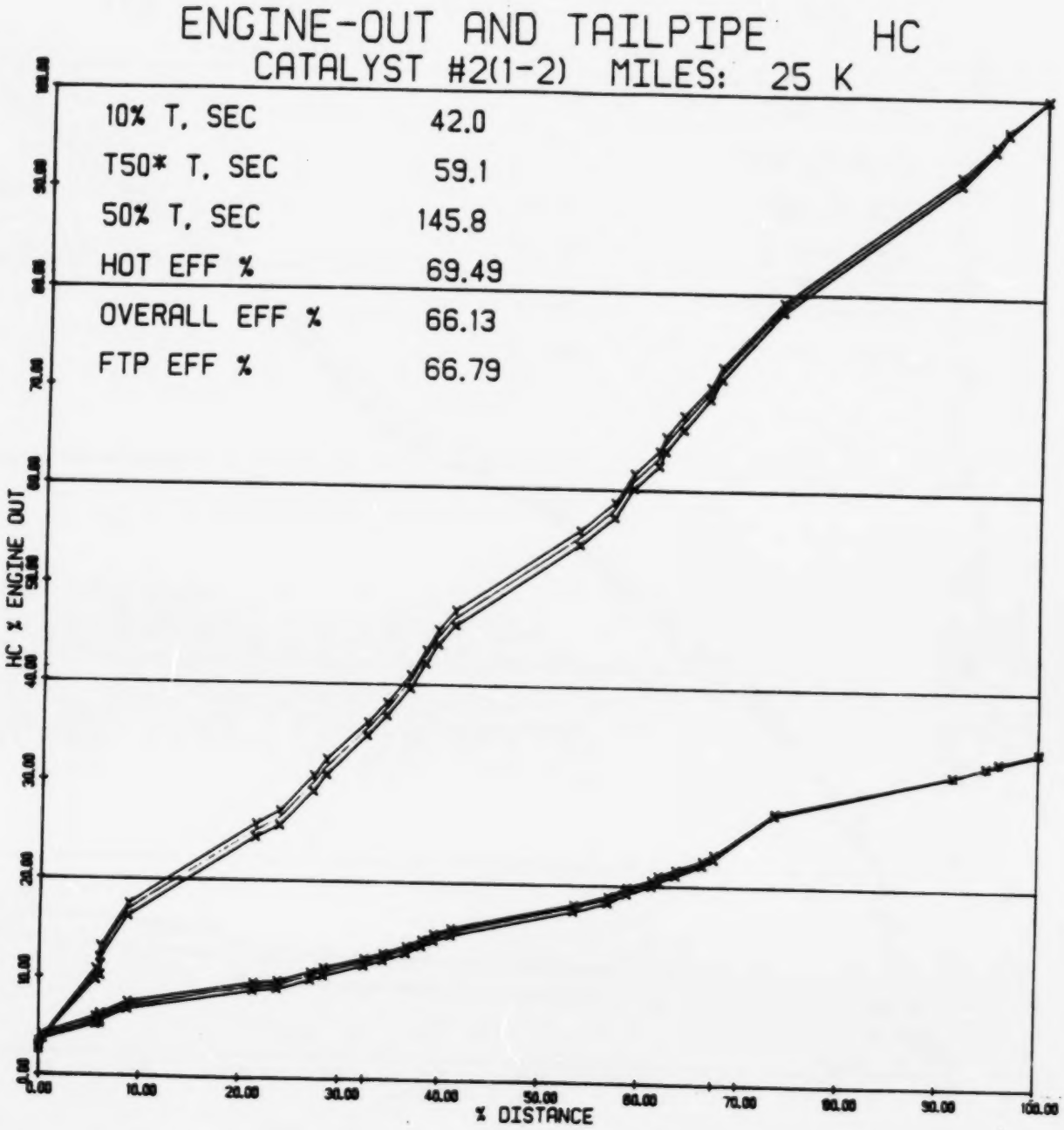
100.00


ENGINE-OUT AND TAILPIPE CO
CATALYST #1(1-1) MILES: 25 K
10% T, SEC 27.1
T50* T, SEC 36.1
50% T, SEC 76.0
HOT EFF % 96.47
OVERALL EFF % 86.42
FTP EFF % 88.73
CO % ENGINE OUT
% DISTANCE


ENGINE-OUT AND TAILPIPE HC
CATALYST #2(1-2) MILES: 25 K
10% T, SEC 42.0
T50* T, SEC 59.1
50% T, SEC 145.8
HOT EFF % 69.49
OVERALL EFF % 66.13
FTP EFF % 66.79
HC % ENGINE OUT
% DISTANCE
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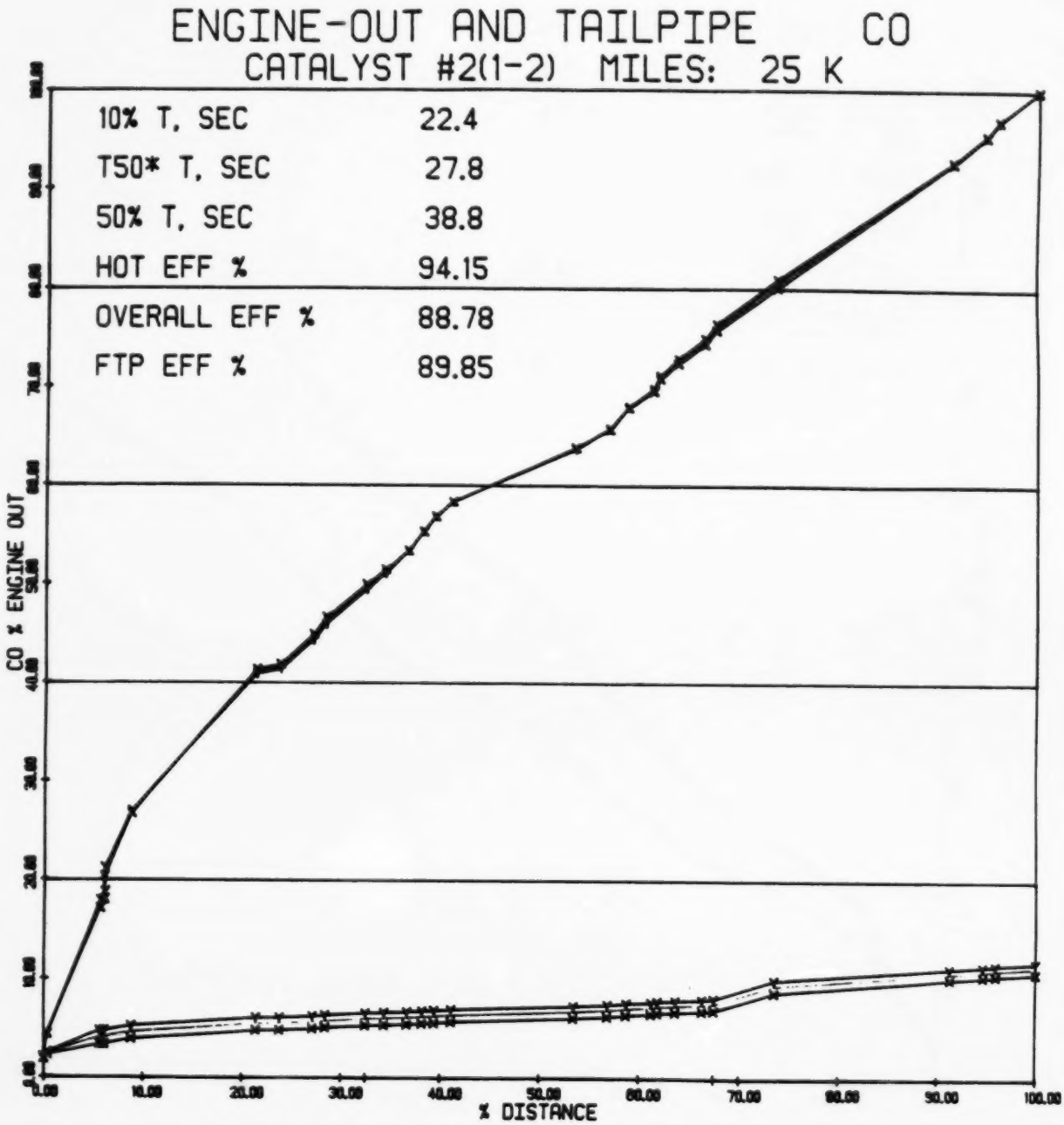
ENGINE-OUT AND TAILPIPE CO
CATALYST #2(1-2) MILES: 25 K
10% T, SEC 22.4
T50* T, SEC 27.8
50% T, SEC 38.8
HOT EFF % 94.15
OVERALL EFF % 88.78
FTP EFF % 89.85
CO % ENGINE OUT
% DISTANCE
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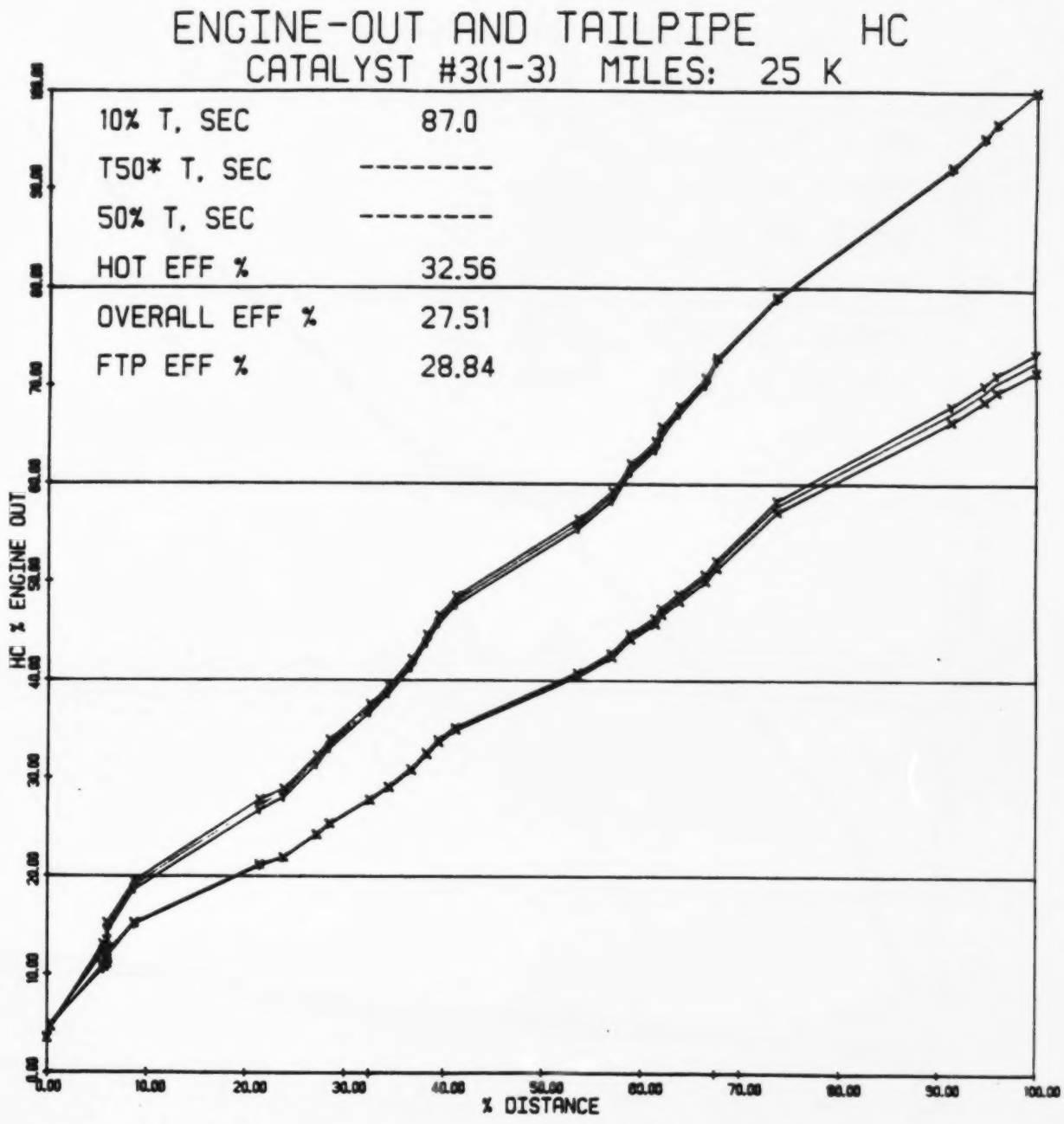
ENGINE-OUT AND TAILPIPE HC
CATALYST #3(1-3) MILES: 25 K
10% T, SEC 87.0
T50* T, SEC --------
50% T, SEC --------
HOT EFF % 32.56
OVERALL EFF % 27.51
FTP EFF % 28.84
HC % ENGINE OUT
% DISTANCE
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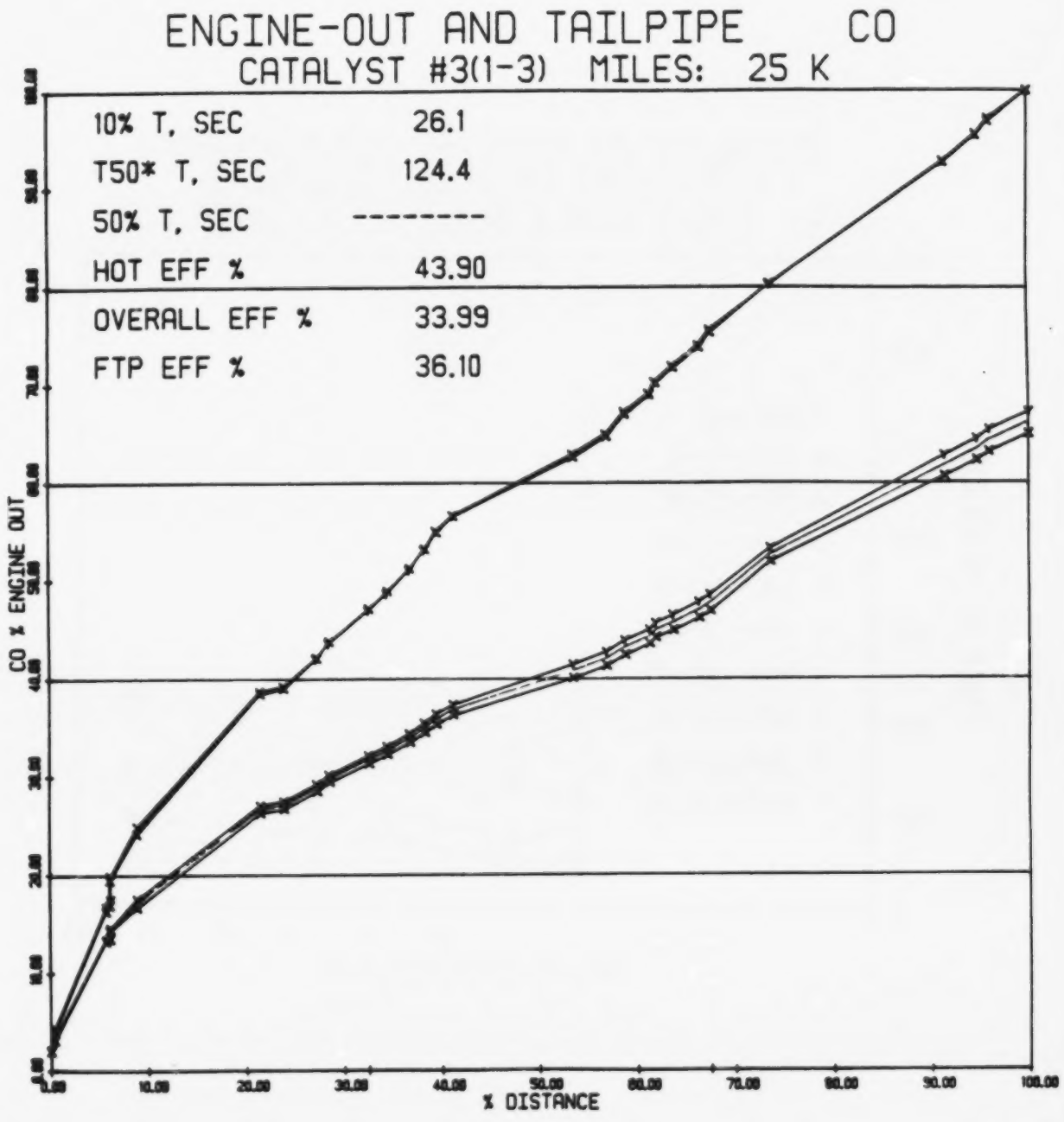
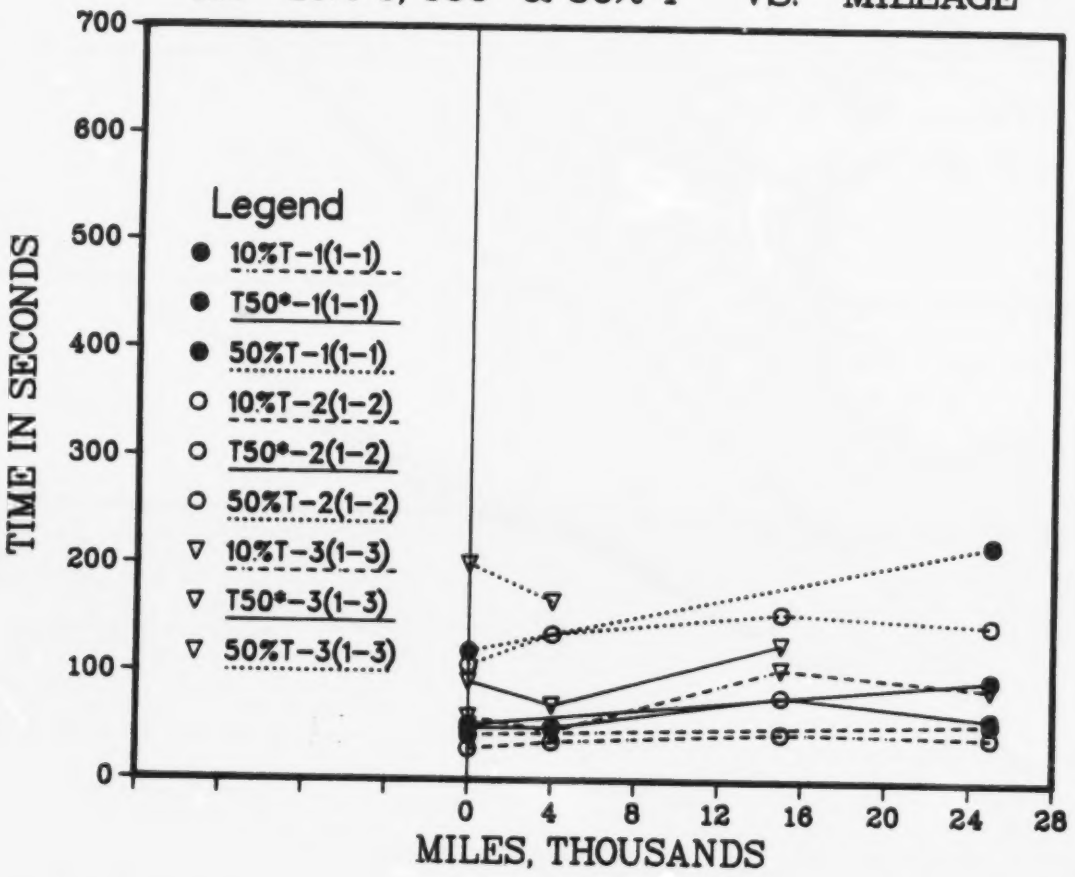
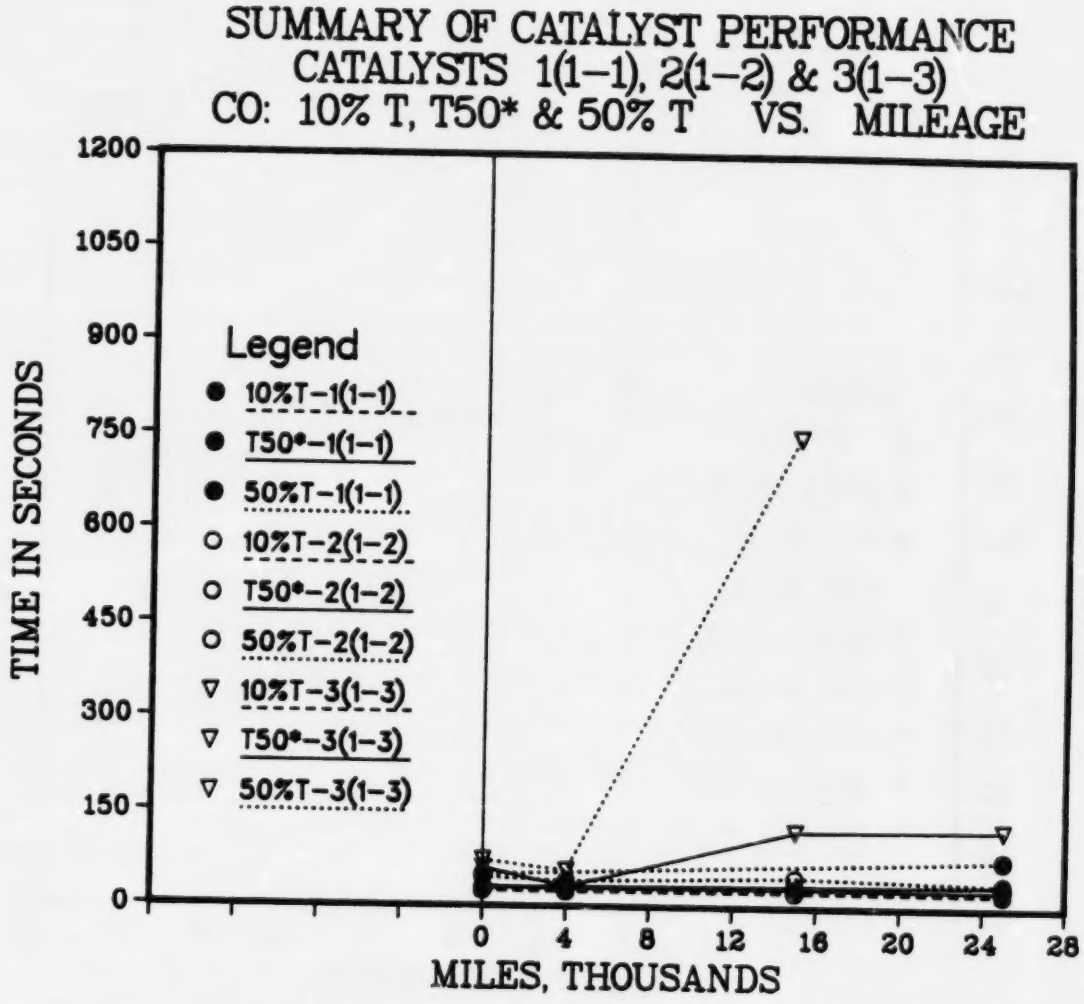
90.00
100.00


ENGINE-OUT AND TAILPIPE CO
CATALYST #3(1-3) MILES: 25 K
10% T, SEC 26.1
T50* T, SEC 124.4
50% T, SEC --------
HOT EFF % 43.90
OVERALL EFF % 33.99
FTP EFF % 36.10
CO % ENGINE OUT
% DISTANCE

SUMMARY OF CATALYST PERFORMANCE
CATALYSTS 1(1–1), 2(1–2) & 3(1–3)
HC 10% T, T50* & 50% T VS. MILEAGE




SUMMARY OF CATALYST PERFORMANCE
CATALYSTS 1(1-1), 2(1-2) & 3(1-3)
CO: 10% T, T50* & 50% T VS. MILEAGE
TIME IN SECONDS
1200
1050
900
750
600
450
300
150
0
Legend
10%T-1(1-1)
T50*-1(1-1)
50%T-1(1-1)
10%T-2(1-2)
T50*-2(1-2)
50%T-2(1-2)
10%T-3(1-3)
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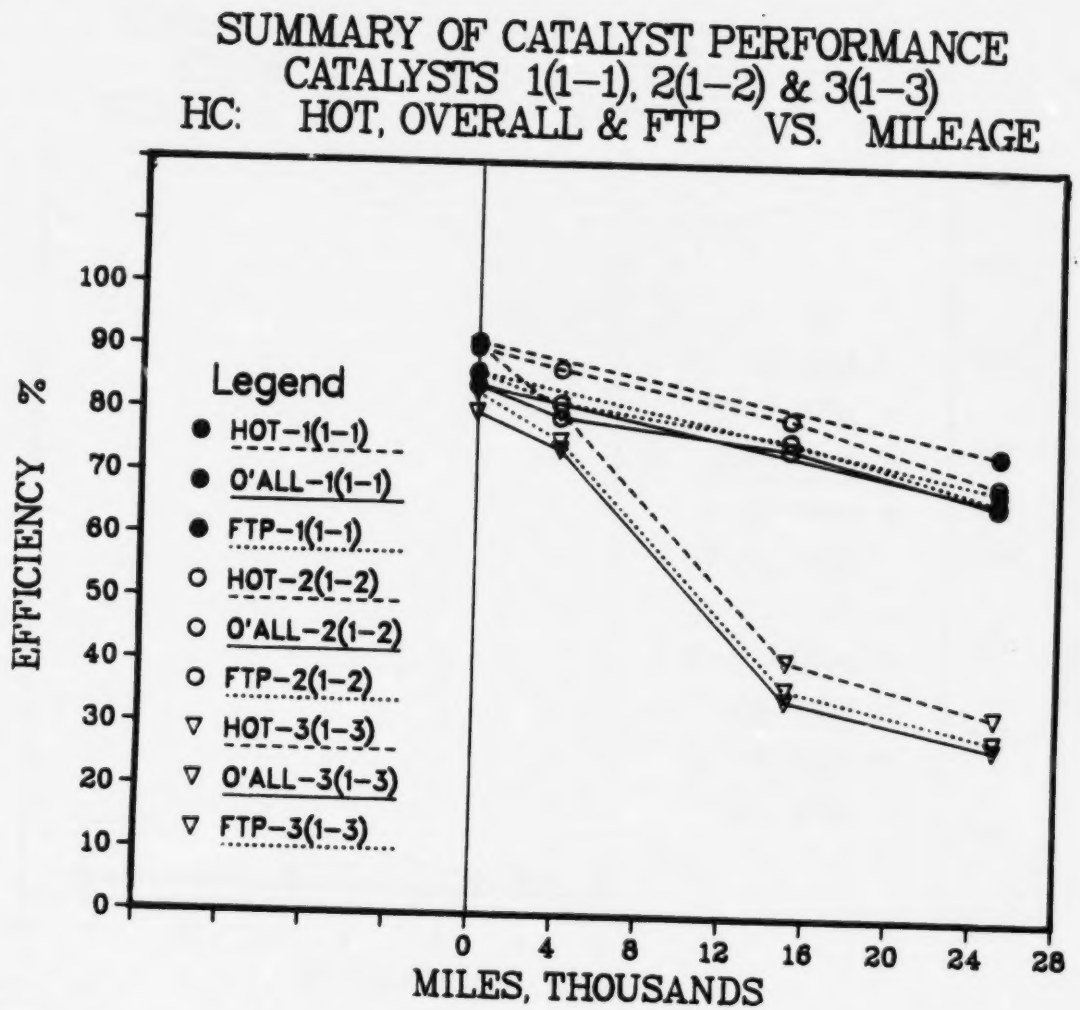
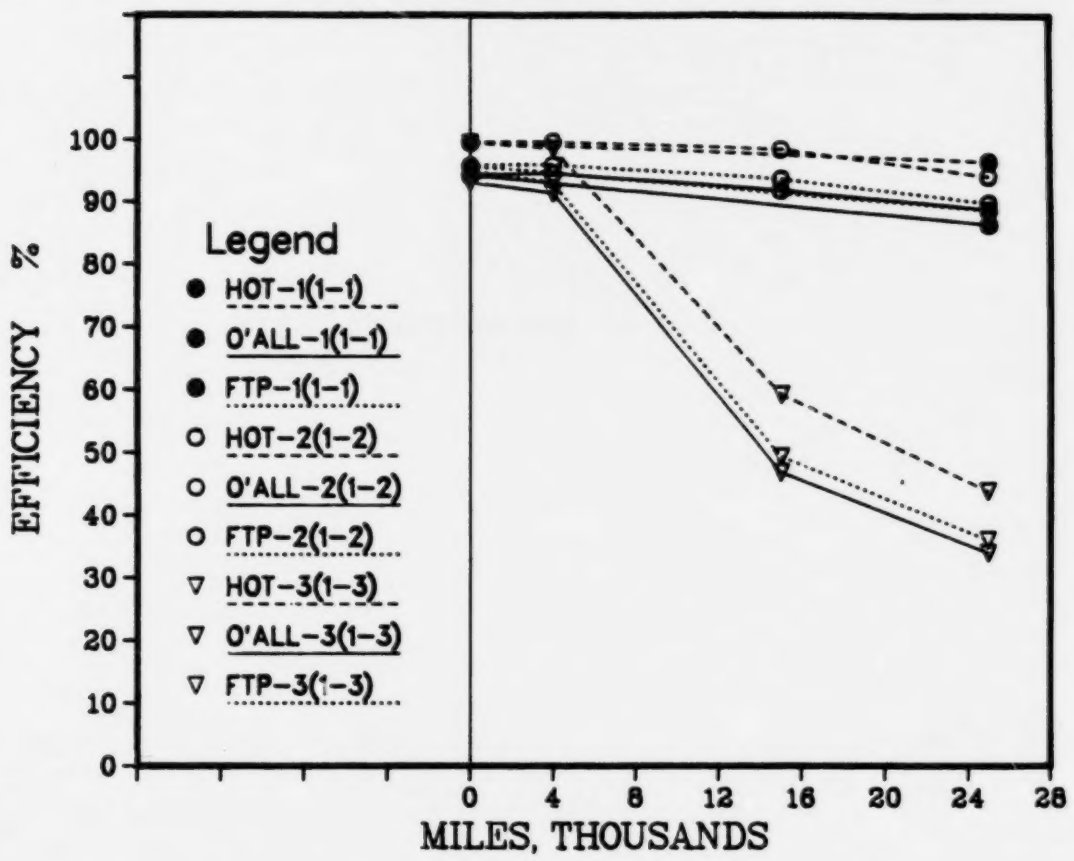
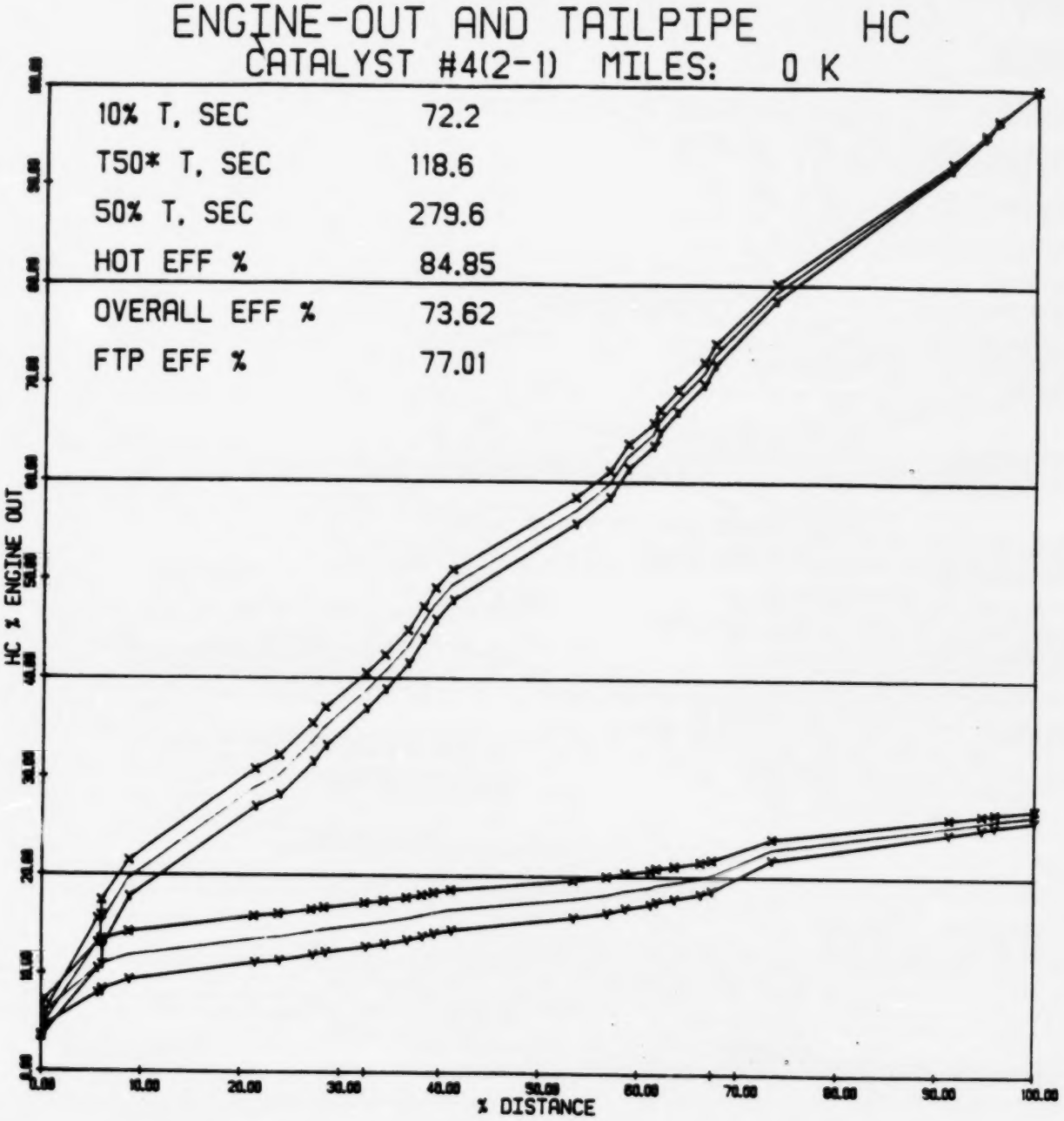
50%T-3(1-3)
0
4
8
12
16
20
24
28
MILES, THOUSANDS


SUMMARY OF CATALYST PERFORMANCE
CATALYSTS 1(1-1), 2(1-2) & 3(1-3)
HC: HOT, OVERALL & FTP VS. MILEAGE
EFFICIENCY %
100
90
80
70
60
50
40
30
20
10
0
Legend
HOT-1(1-1)
O'ALL-1(1-1)
FTP-1(1-1)
HOT-2(1-2)
O'ALL-2(1-2)
FTP-2(1-2)
HOT-3(1-3)
O'ALL-3(1-3)
FTP-3(1-3)
0
4
8
12
16
20
24
28
MILES, THOUSANDS

SUMMARY OF CATALYST PERFORMANCE
CATALYSTS 1(1–1), 2(1–2) & 3(1–3)
CO: HOT, OVERALL & FTP VS. MILEAGE



Echlin Catalyst Data



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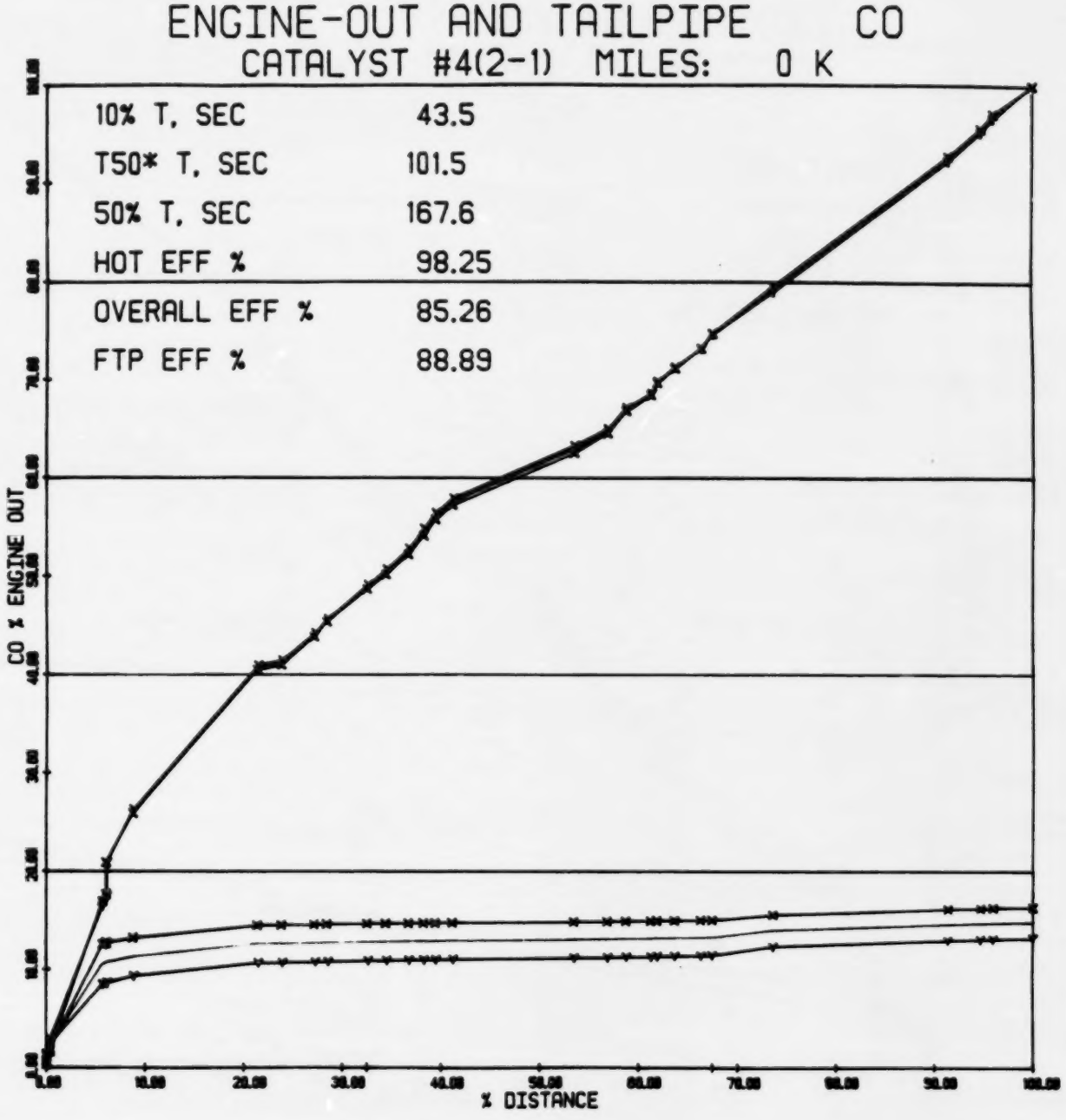
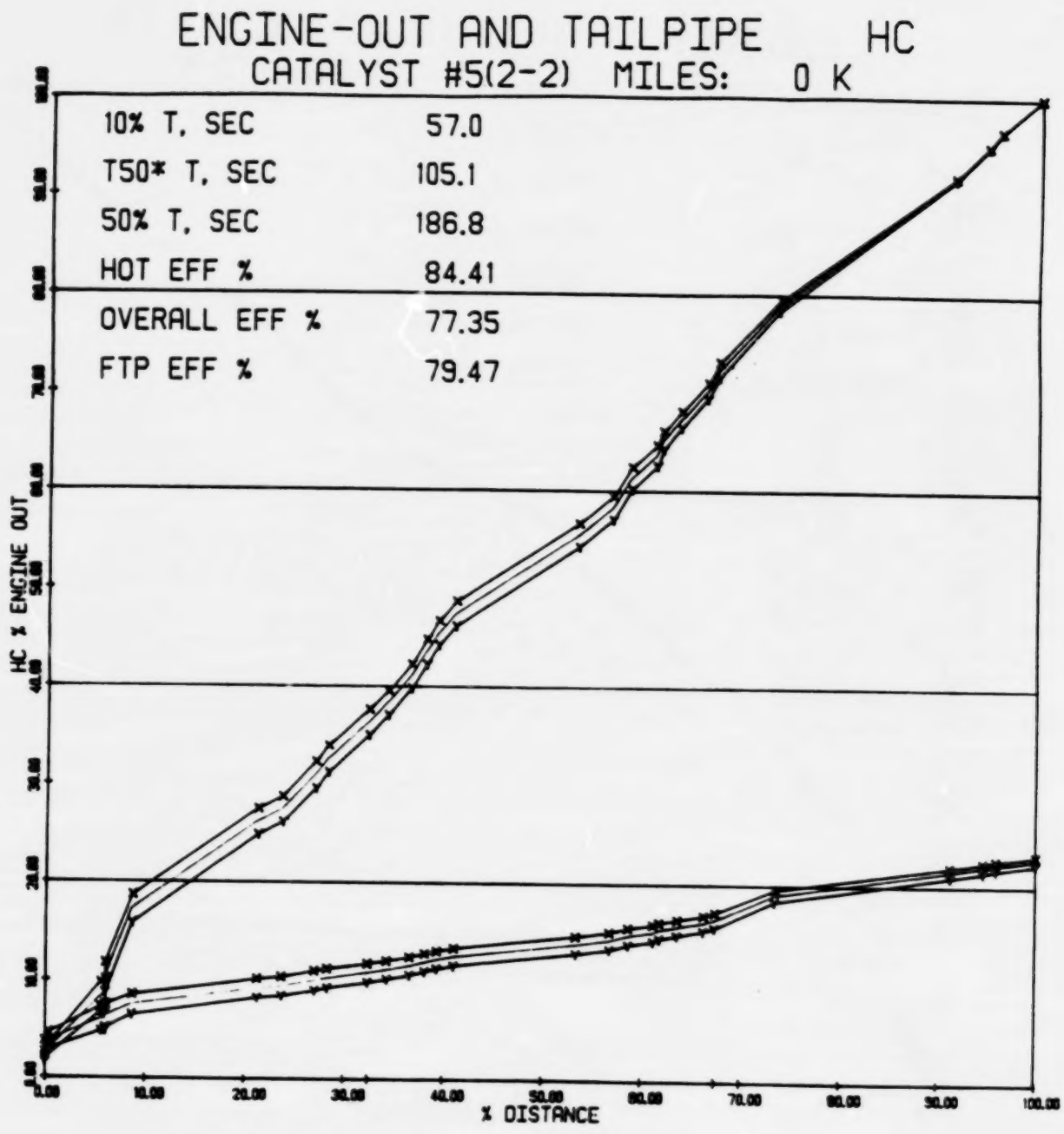
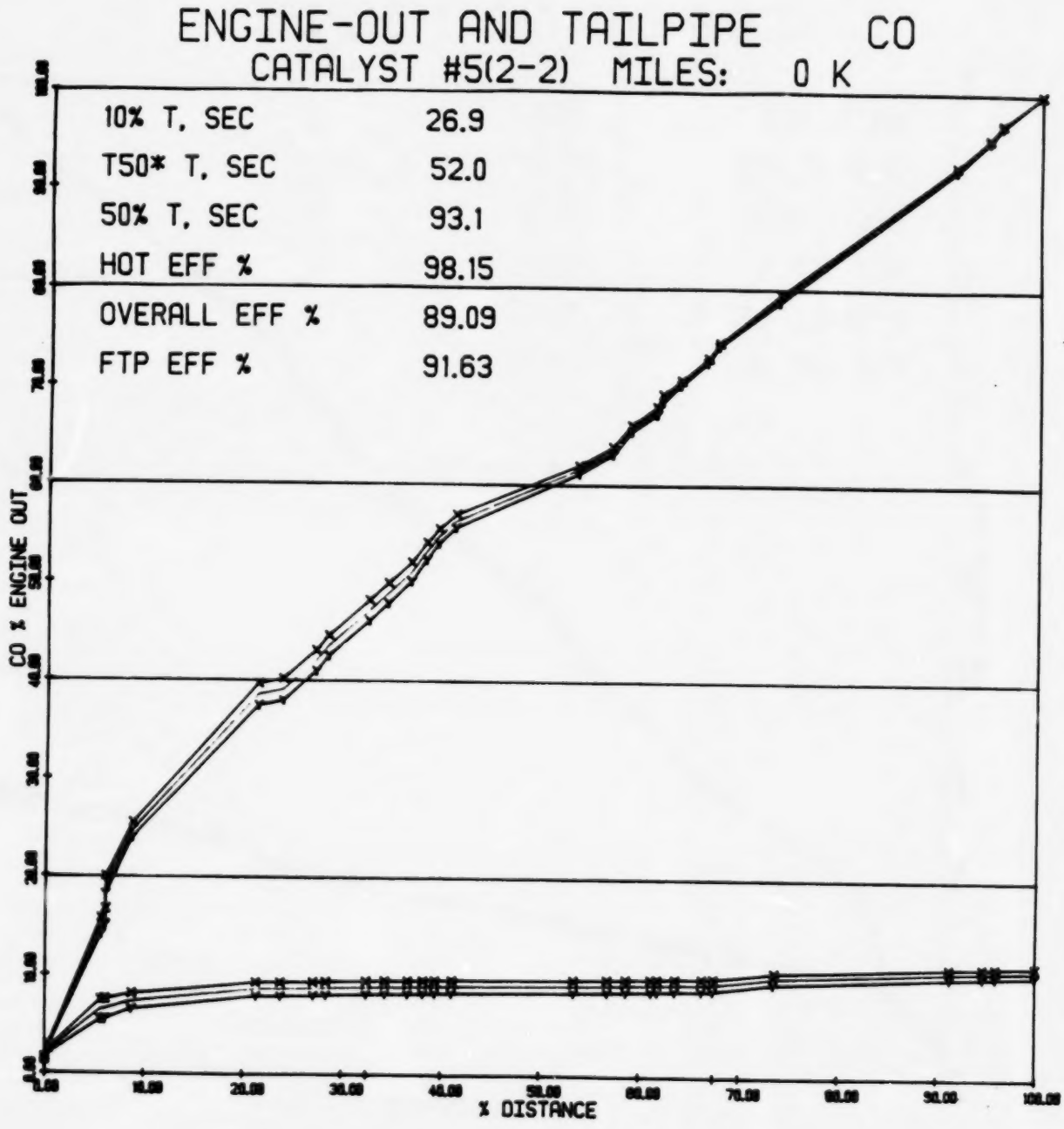
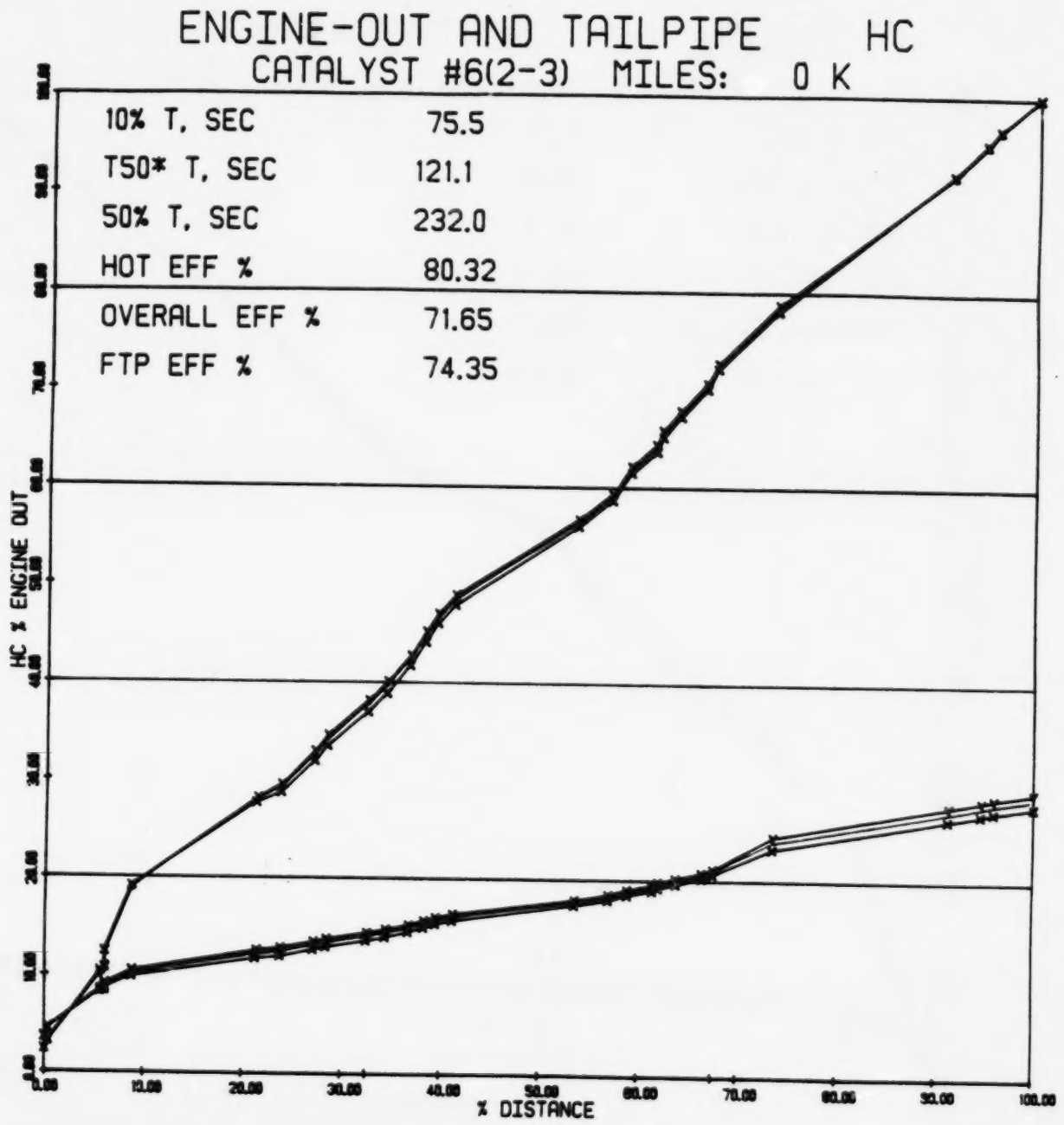
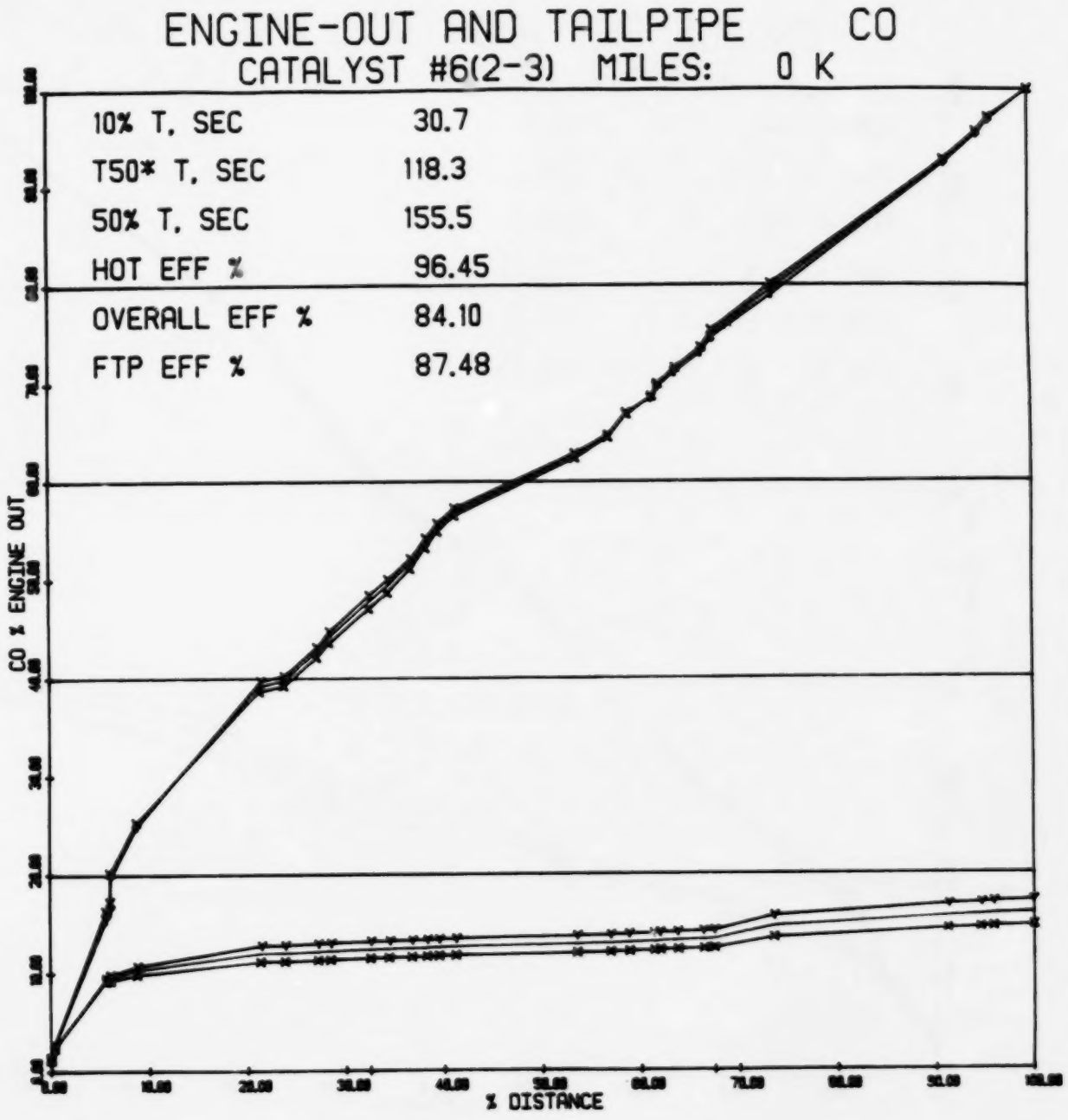
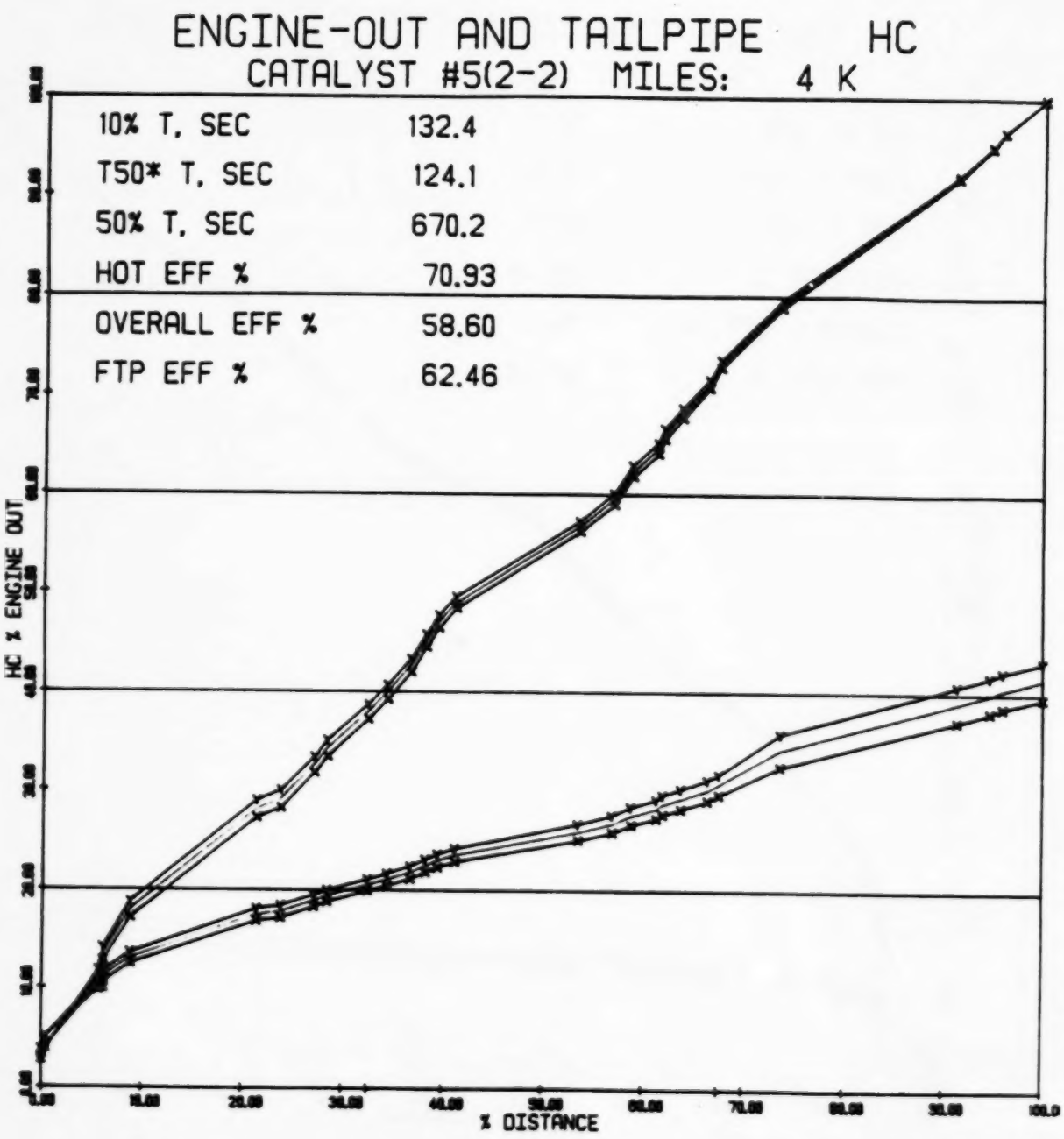

ENGINE-OUT AND TAILPIPE CO
CATALYST #4(2-1) MILES: 0 K
10% T, SEC 43.5
T50* T, SEC 101.5
50% T, SEC 167.6
HOT EFF % 98.25
OVERALL EFF % 85.26
FTP EFF % 88.89
CO % ENGINE OUT
% DISTANCE

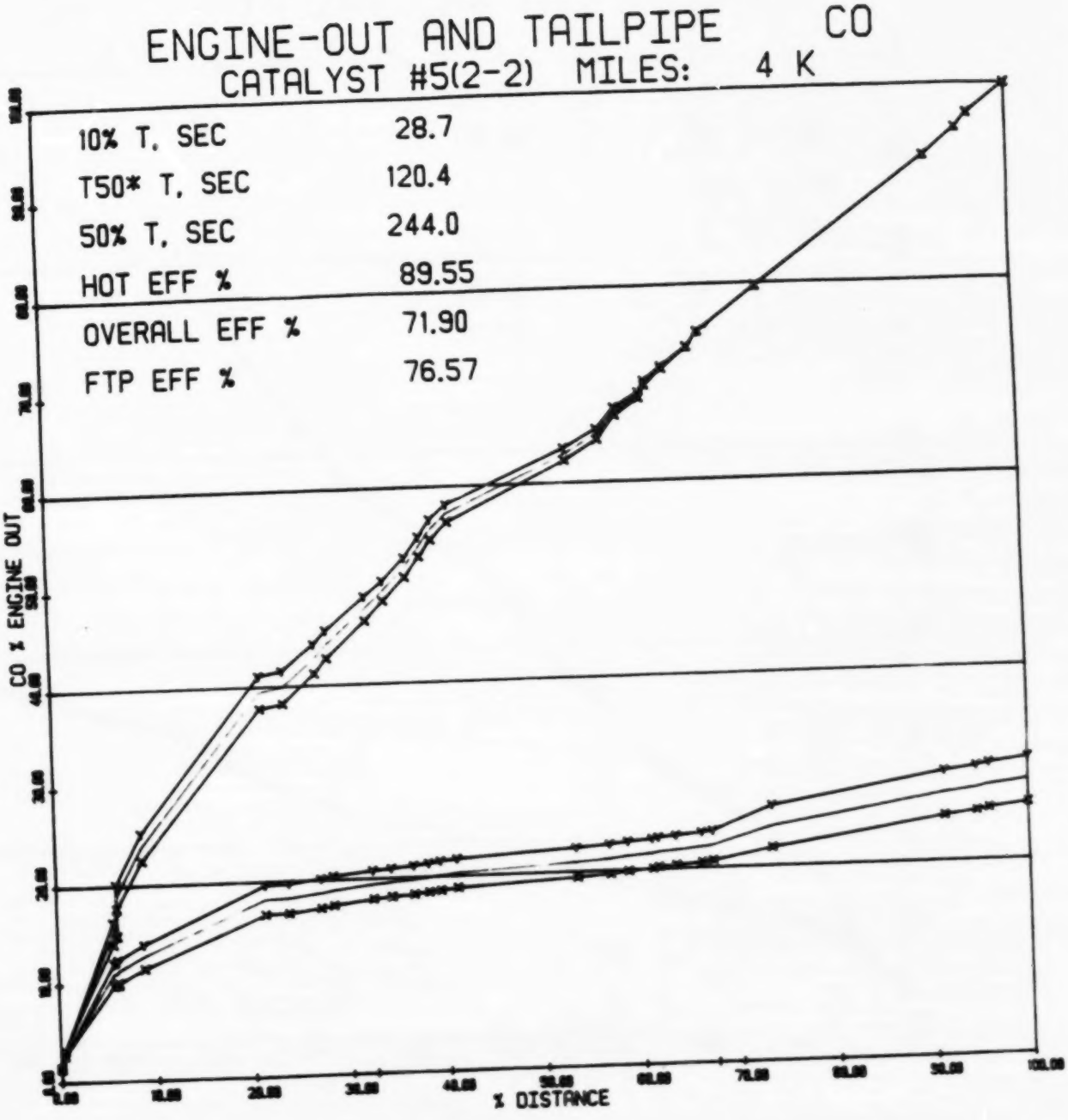

ENGINE-OUT AND TAILPIPE HC
CATALYST #5(2-2) MILES: 0 K
10% T, SEC 57.0
T50* T, SEC 105.1
50% T, SEC 186.8
HOT EFF % 84.41
OVERALL EFF % 77.35
FTP EFF % 79.47
HC % ENGINE OUT
% DISTANCE
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

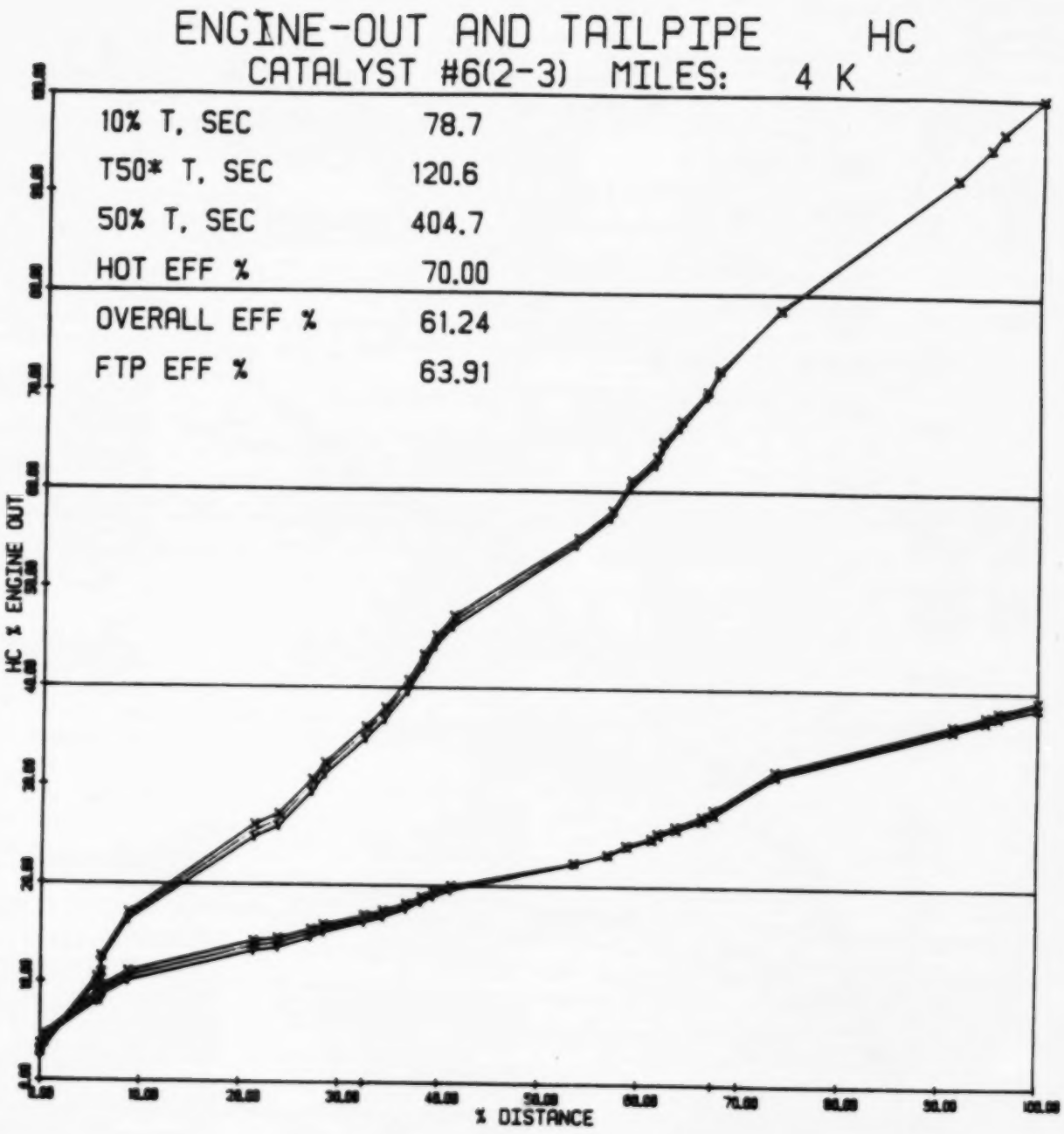

ENGINE-OUT AND TAILPIPE CO
CATALYST #5(2-2) MILES: 0 K
10% T, SEC 26.9
T50* T, SEC 52.0
50% T, SEC 93.1
HOT EFF % 98.15
OVERALL EFF % 89.09
FTP EFF % 91.63
CO % ENGINE OUT
% DISTANCE

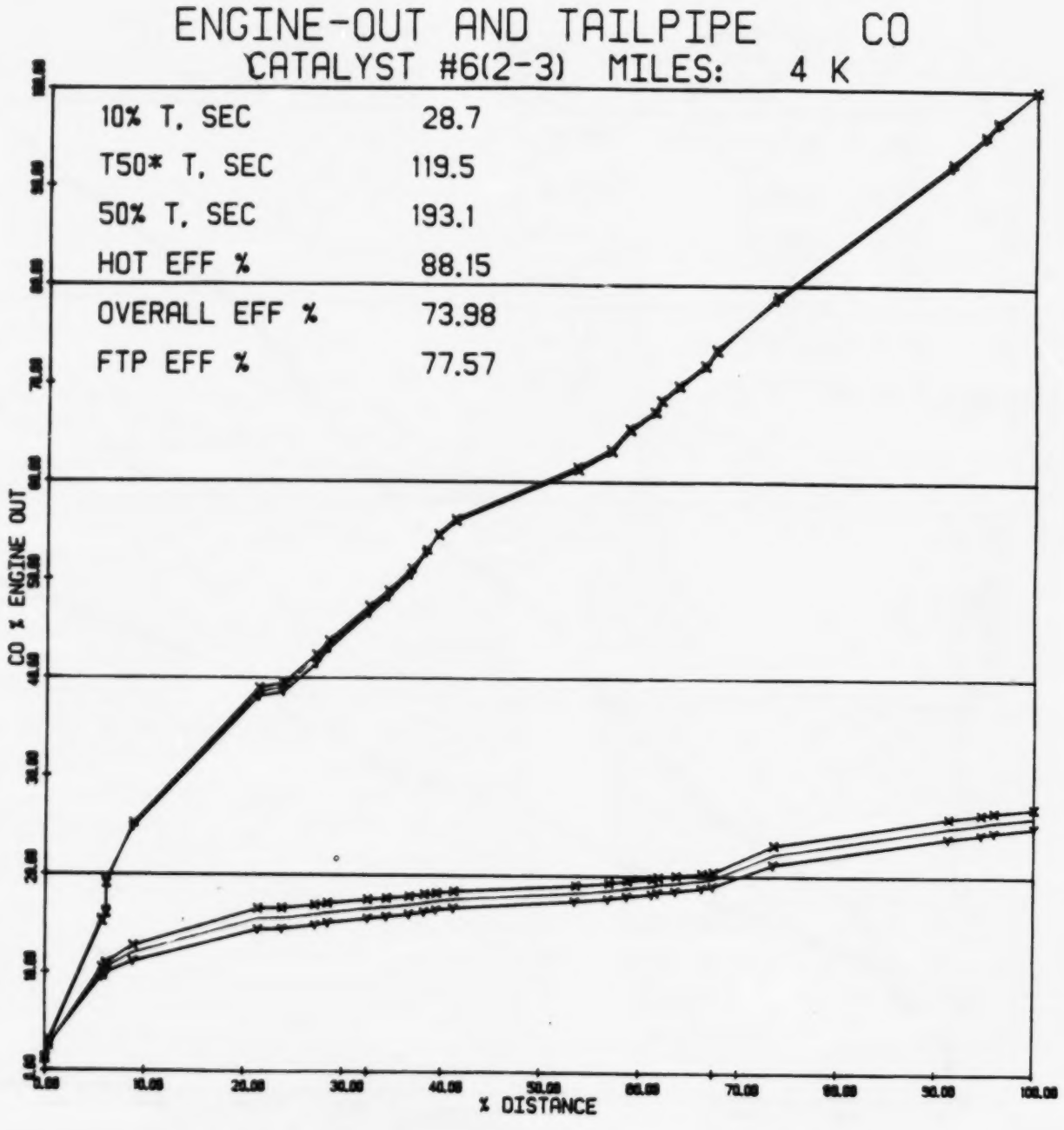

ENGINE-OUT AND TAILPIPE HC
CATALYST #6(2-3) MILES: 0 K
10% T, SEC 75.5
T50* T, SEC 121.1
50% T, SEC 232.0
HOT EFF % 80.32
OVERALL EFF % 71.65
FTP EFF % 74.35
HC % ENGINE OUT
% DISTANCE

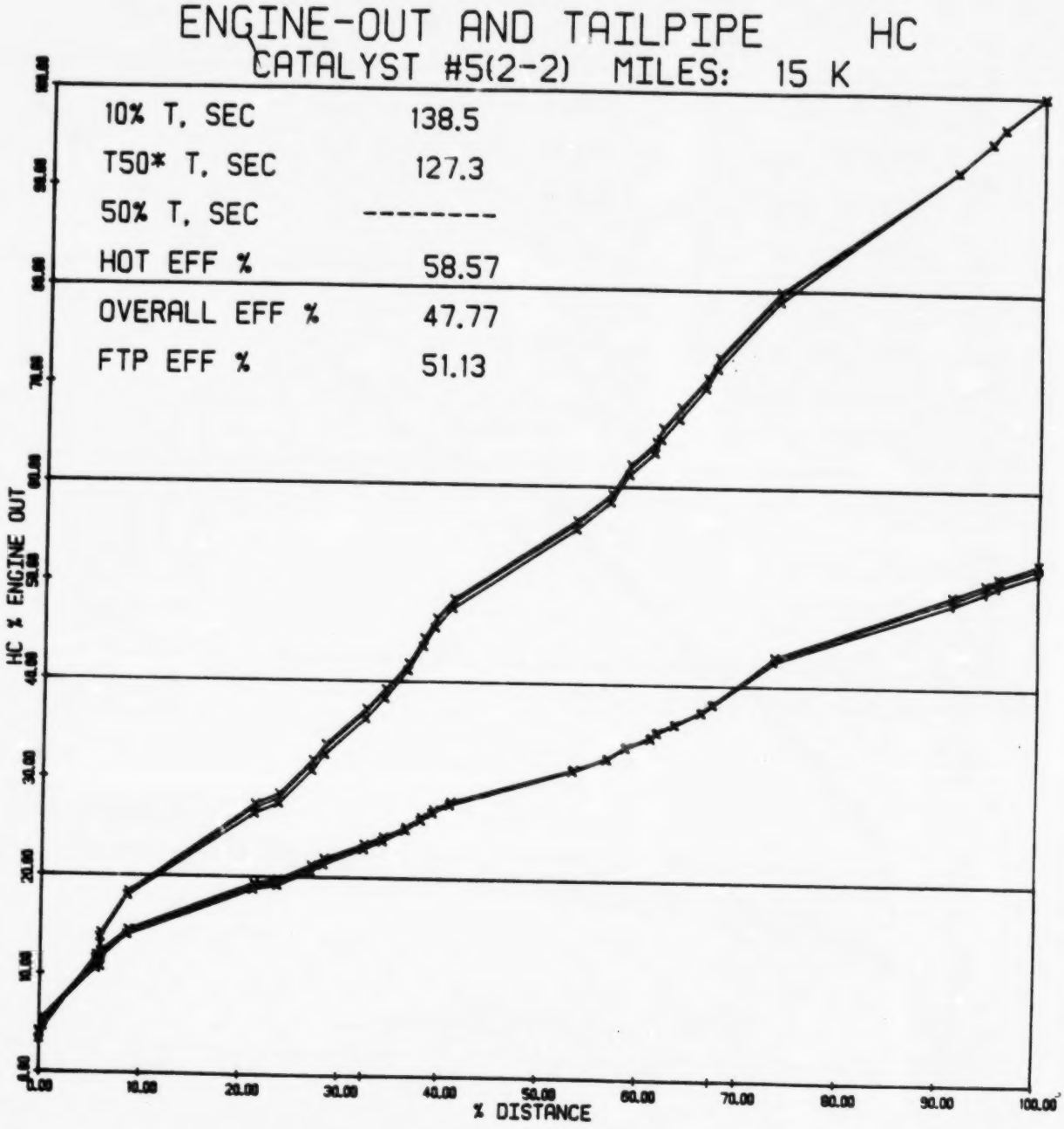

ENGINE-OUT AND TAILPIPE CO
CATALYST #6(2-3) MILES: 0 K
10% T, SEC 30.7
T50* T, SEC 118.3
50% T, SEC 155.5
HOT EFF % 96.45
OVERALL EFF % 84.10
FTP EFF % 87.48
CO % ENGINE OUT
% DISTANCE

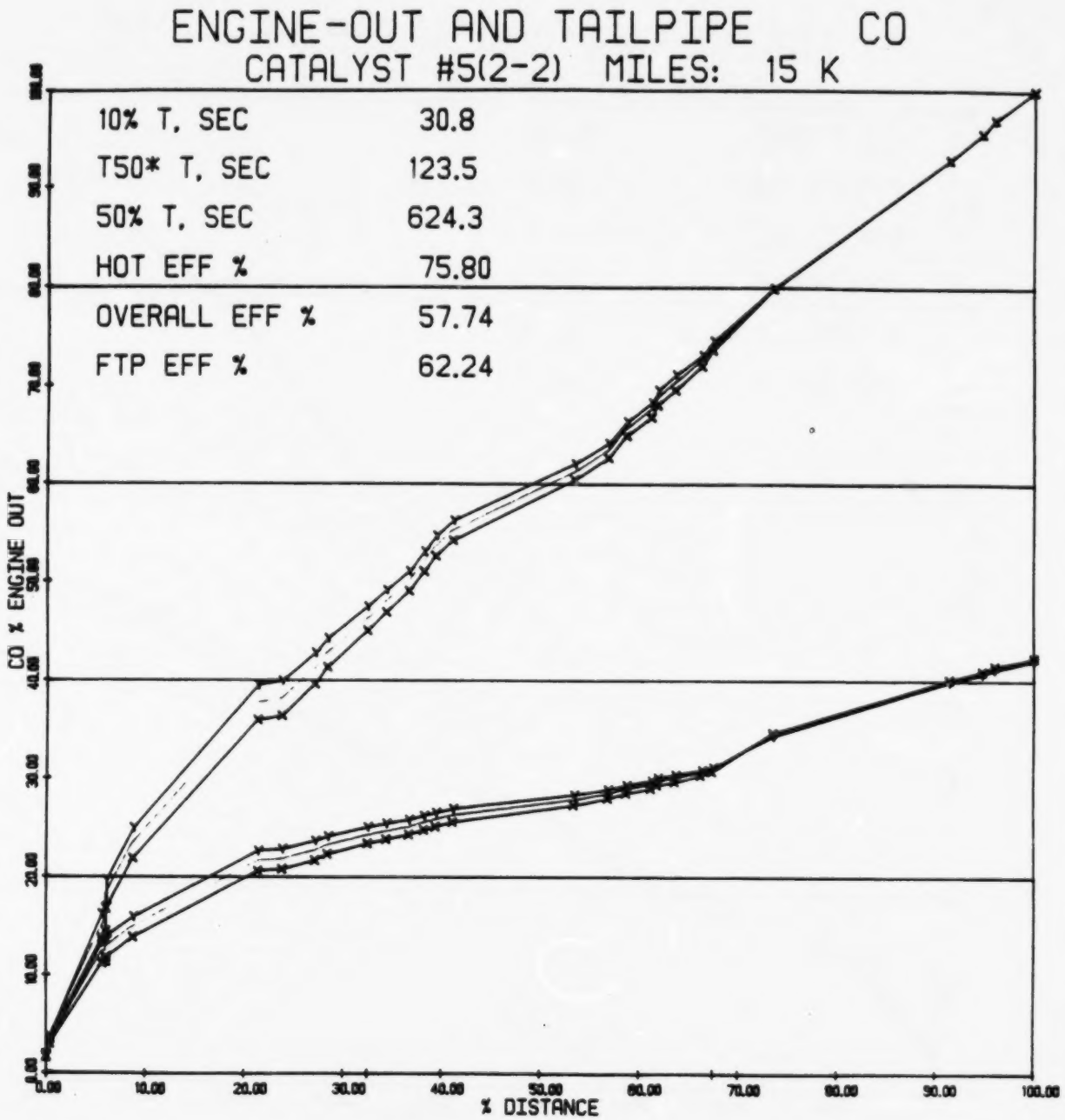

ENGINE-OUT AND TAILPIPE HC
CATALYST #5(2-2) MILES: 4 K
10% T, SEC 132.4
T50* T, SEC 124.1
50% T, SEC 670.2
HOT EFF % 70.93
OVERALL EFF % 58.60
FTP EFF % 62.46
HC % ENGINE OUT
% DISTANCE

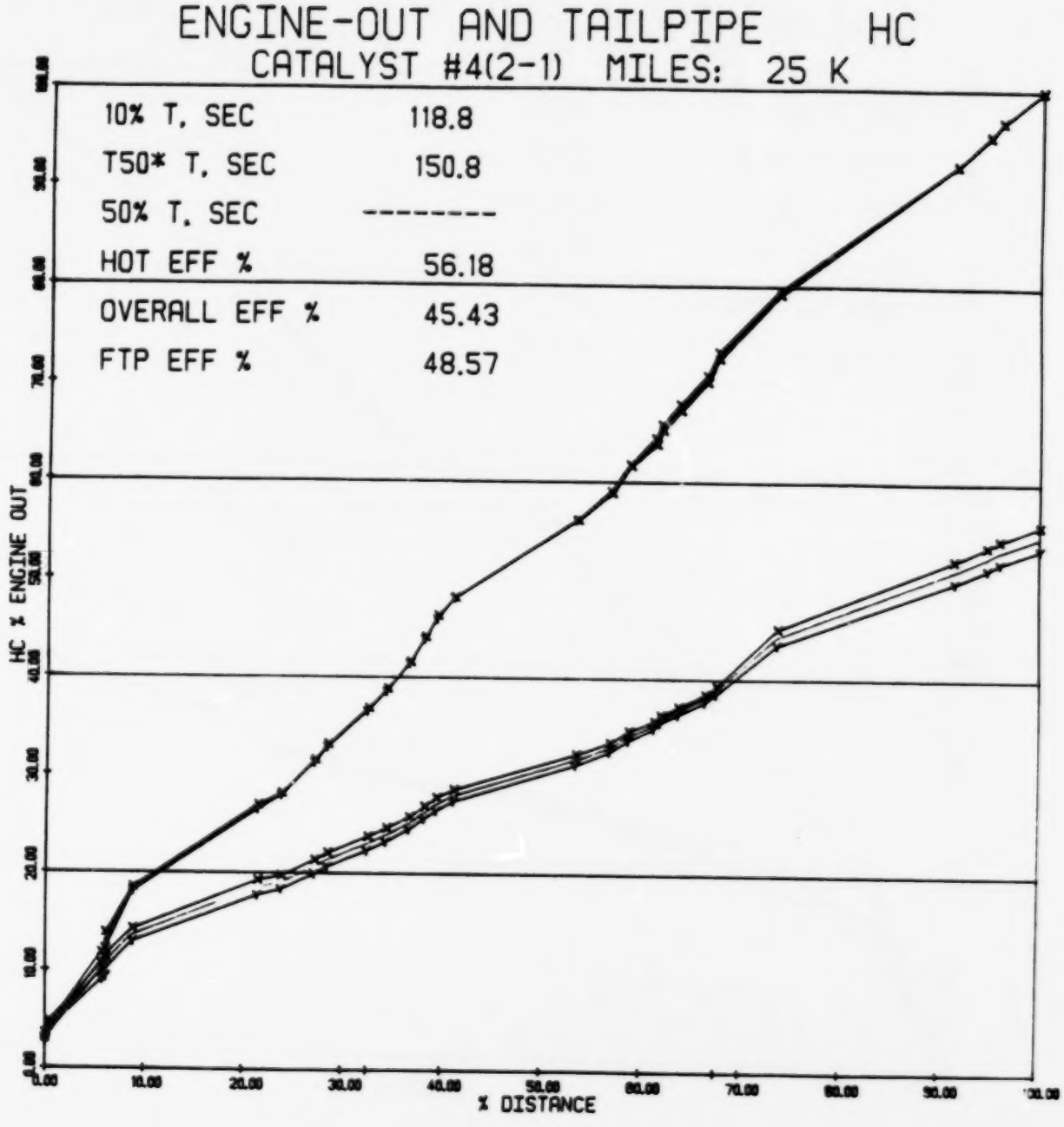

ENGINE-OUT AND TAILPIPE CO
CATALYST #5(2-2) MILES: 4 K
10% T, SEC 28.7
T50* T, SEC 120.4
50% T, SEC 244.0
HOT EFF % 89.55
OVERALL EFF % 71.90
FTP EFF % 76.57
CO % ENGINE OUT
% DISTANCE

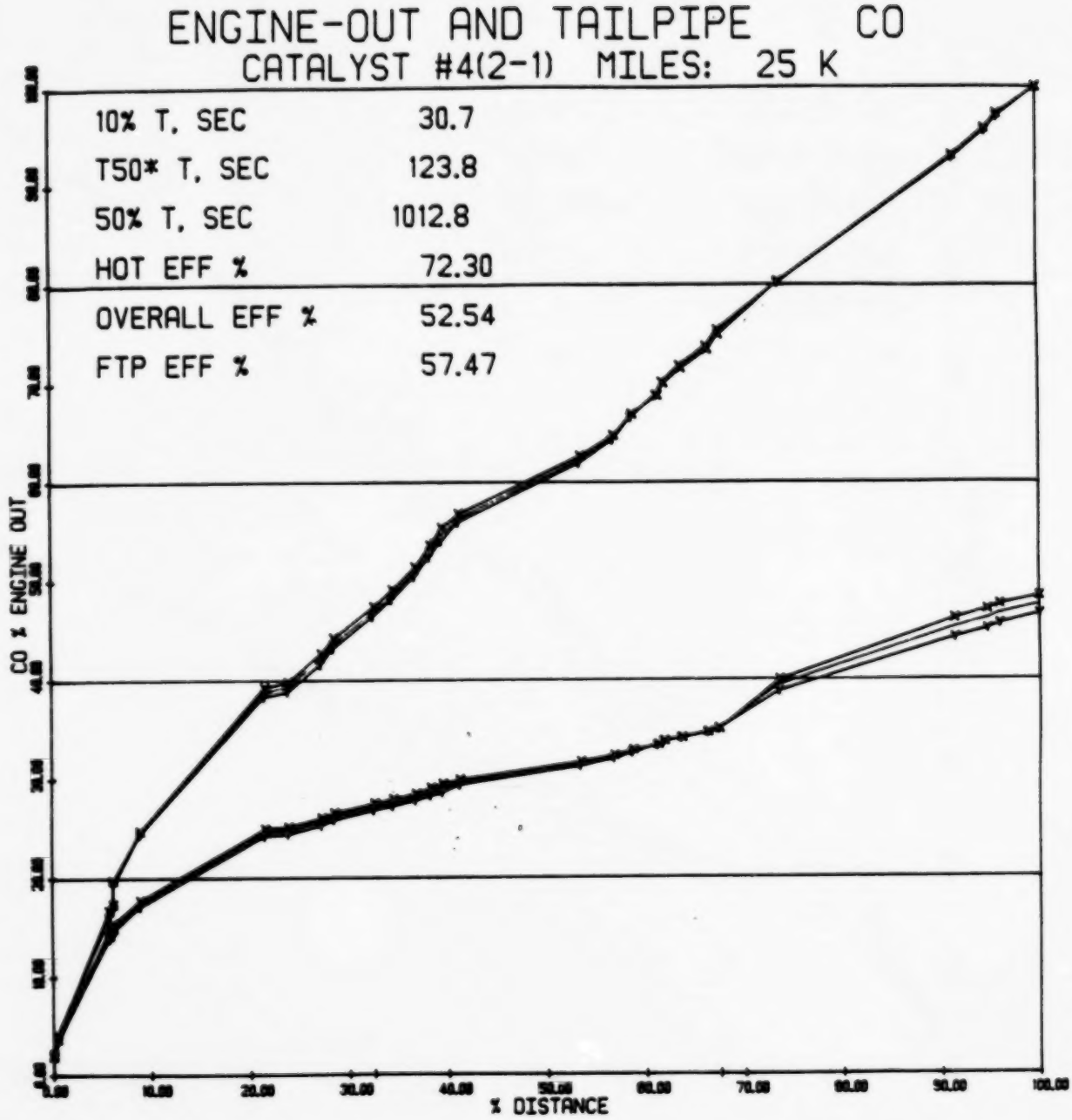

ENGINE-OUT AND TAILPIPE HC
CATALYST #6(2-3) MILES: 4 K
10% T, SEC 78.7
T50* T, SEC 120.6
50% T, SEC 404.7
HOT EFF % 70.00
OVERALL EFF % 61.24
FTP EFF % 63.91
HC % ENGINE OUT
% DISTANCE

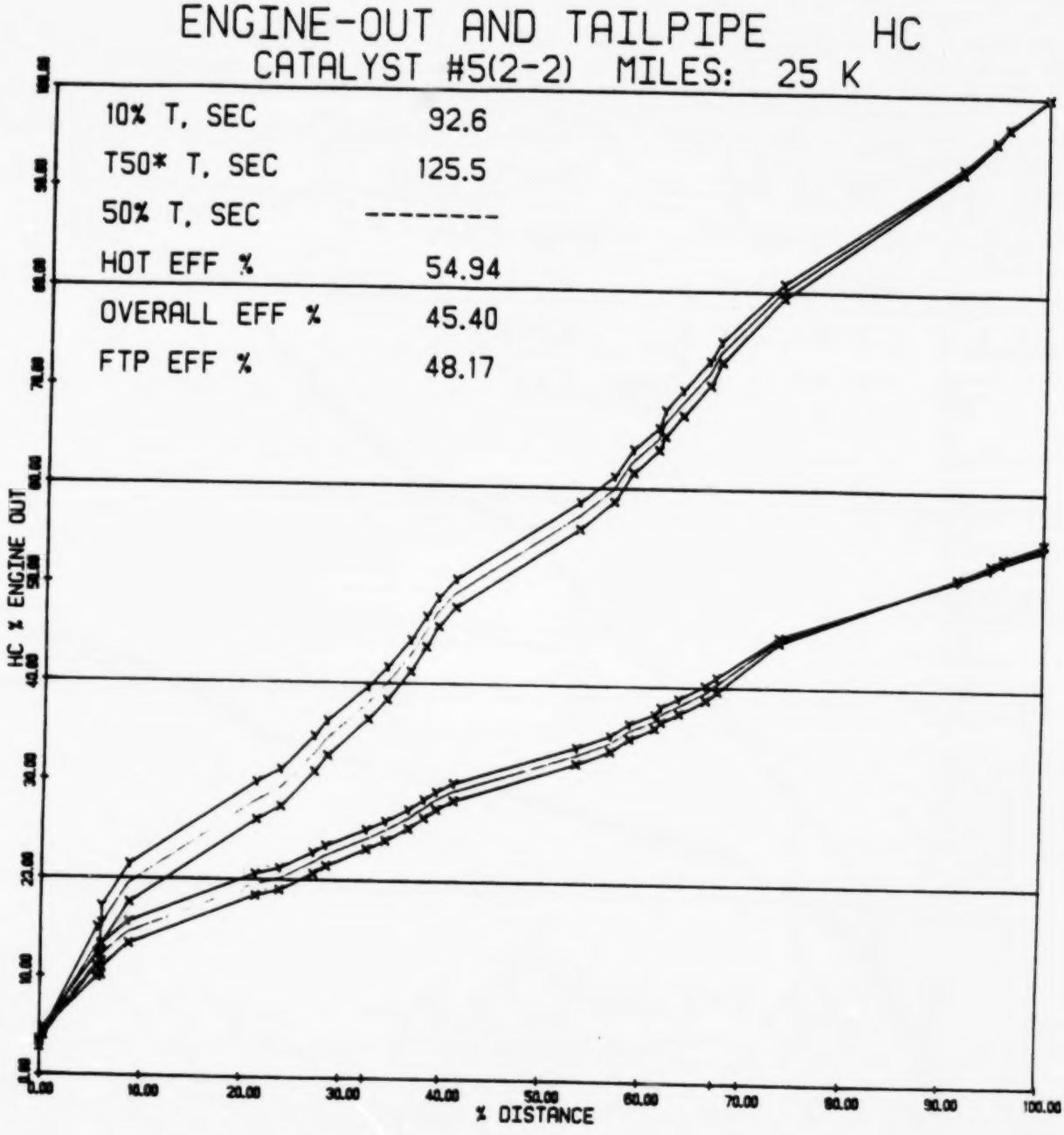

ENGINE-OUT AND TAILPIPE CO
CATALYST #6(2-3) MILES: 4 K
10% T, SEC 28.7
T50* T, SEC 119.5
50% T, SEC 193.1
HOT EFF % 88.15
OVERALL EFF % 73.98
FTP EFF % 77.57
CO % ENGINE OUT
% DISTANCE

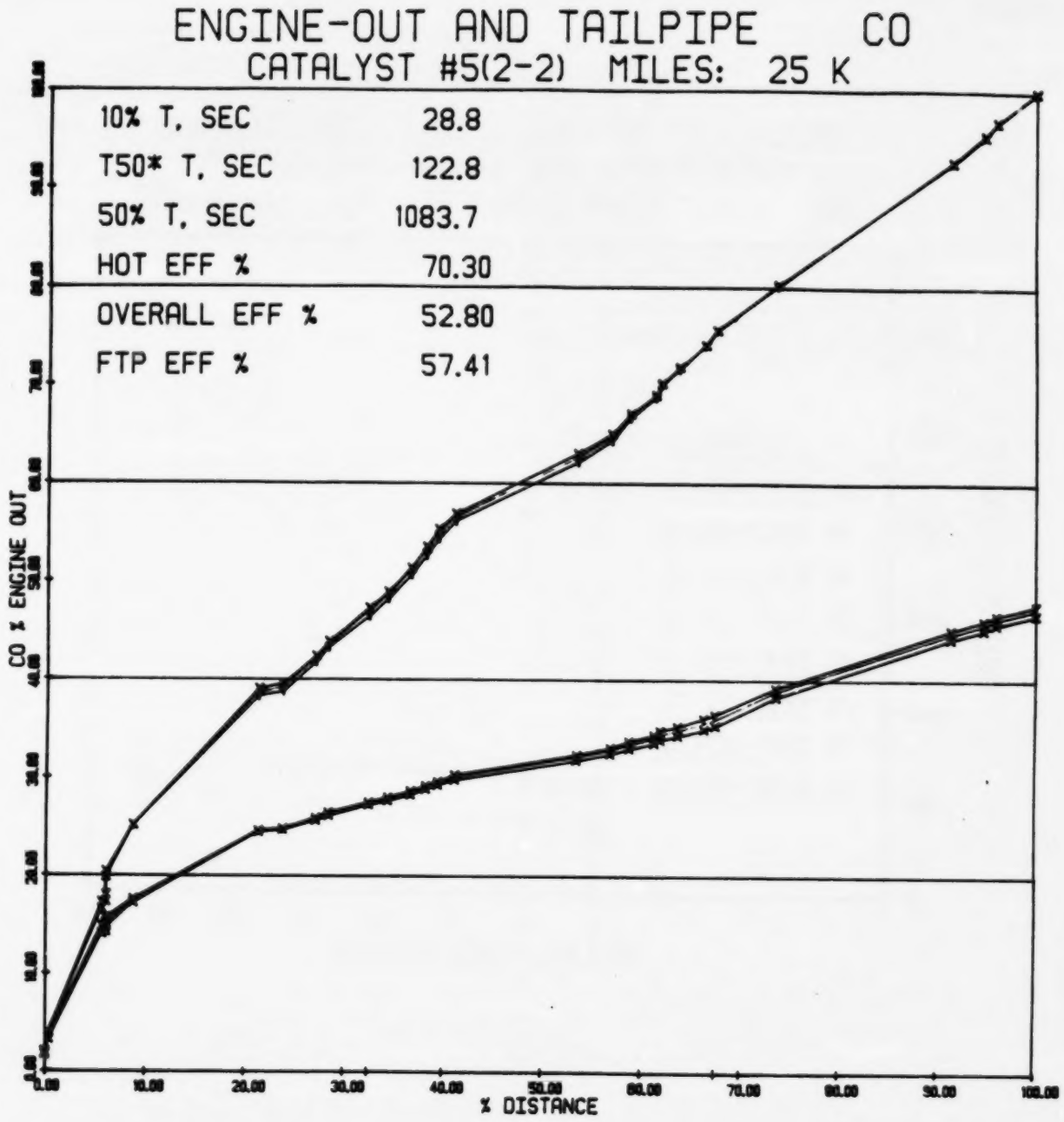

ENGINE-OUT AND TAILPIPE HC
CATALYST #5(2-2) MILES: 15 K
10% T. SEC 138.5
T50* T. SEC 127.3
50% T. SEC --------
HOT EFF % 58.57
OVERALL EFF % 47.77
FTP EFF % 51.13
HC % ENGINE OUT
% DISTANCE
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

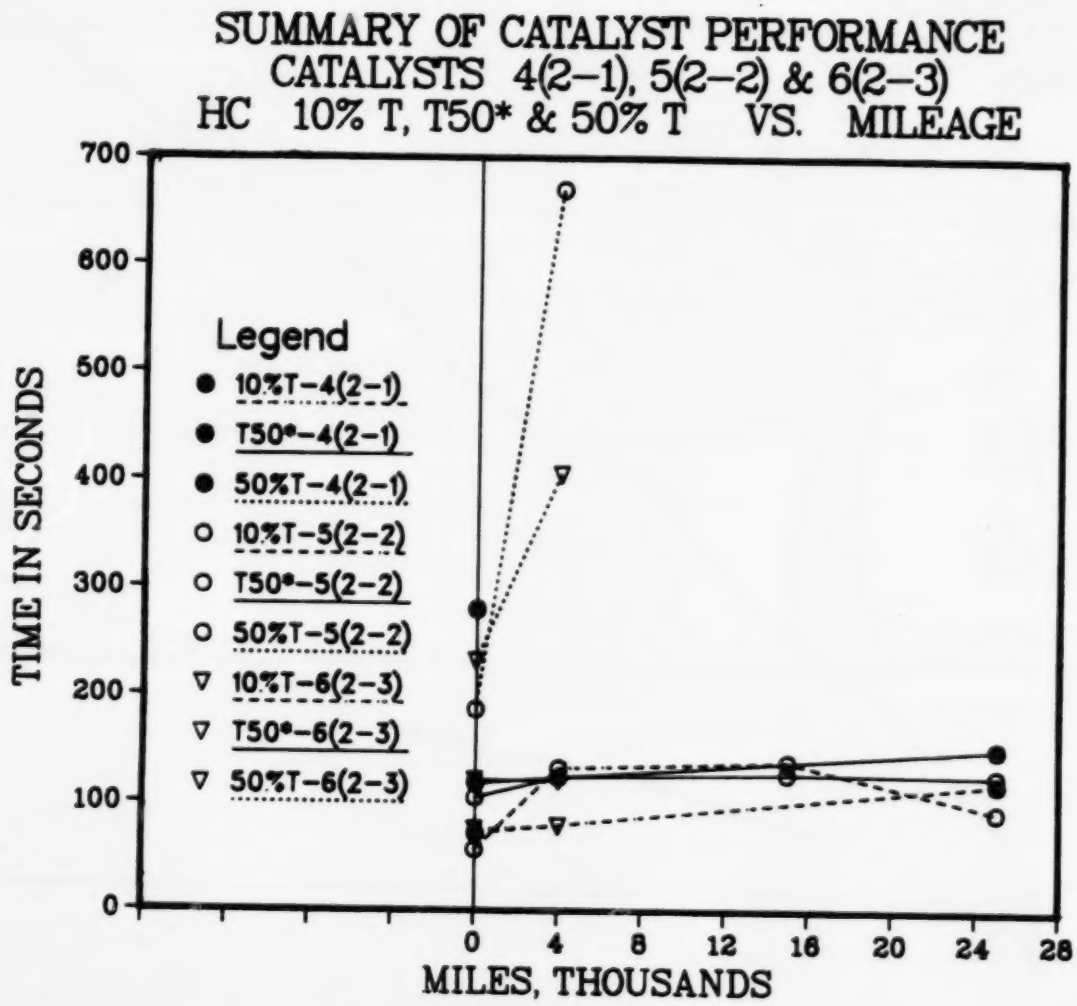

ENGINE-OUT AND TAILPIPE CO
CATALYST #5(2-2) MILES: 15 K
10% T, SEC 30.8
T50* T, SEC 123.5
50% T, SEC 624.3
HOT EFF % 75.80
OVERALL EFF % 57.74
FTP EFF % 62.24
CO % ENGINE OUT
% DISTANCE
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

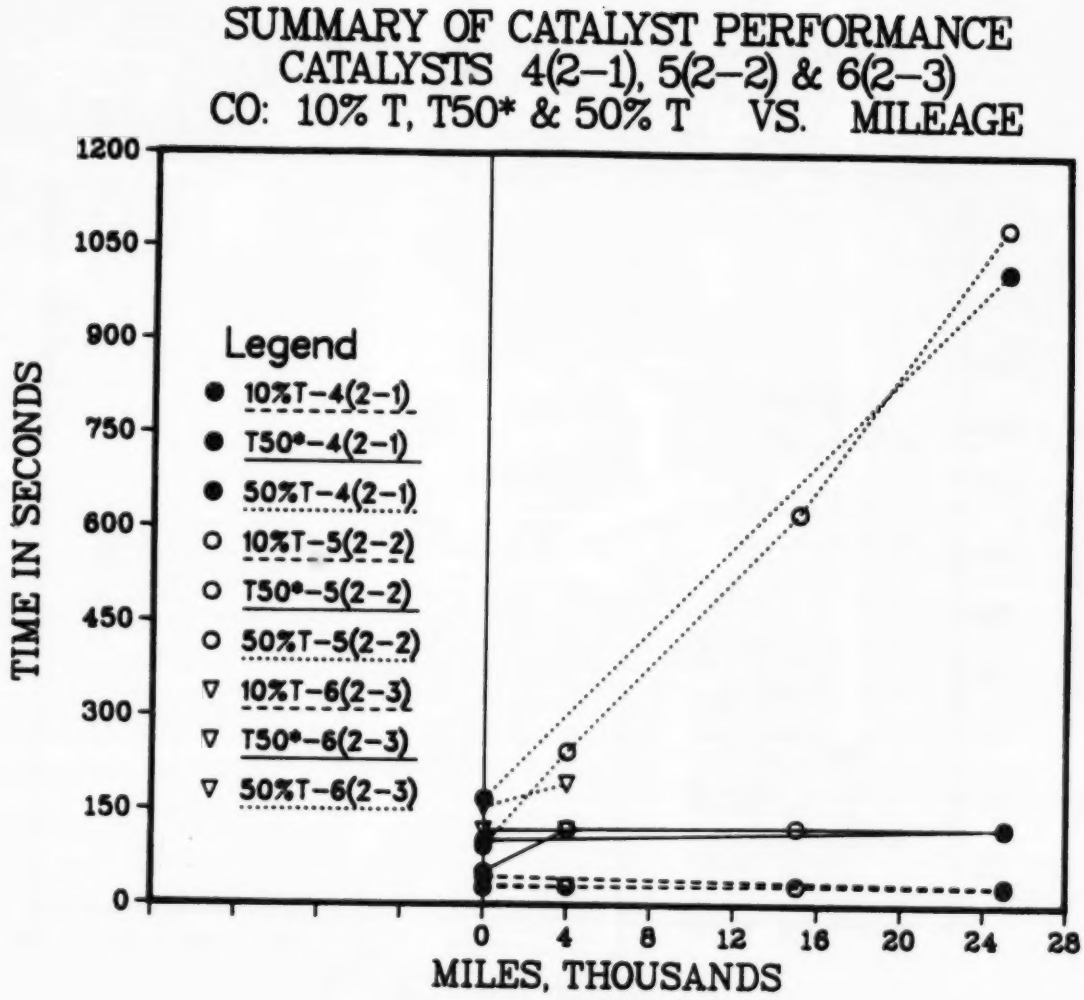

ENGINE-OUT AND TAILPIPE HC
CATALYST #4(2-1) MILES: 25 K
10% T, SEC 118.8
T50* T, SEC 150.8
50% T, SEC --------
HOT EFF % 56.18
OVERALL EFF % 45.43
FTP EFF % 48.57
HC % ENGINE OUT
% DISTANCE
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00


ENGINE-OUT AND TAILPIPE CO
CATALYST #4(2-1) MILES: 25 K
10% T, SEC 30.7
T50* T, SEC 123.8
50% T, SEC 1012.8
HOT EFF % 72.30
OVERALL EFF % 52.54
FTP EFF % 57.47
CO % ENGINE OUT
% DISTANCE

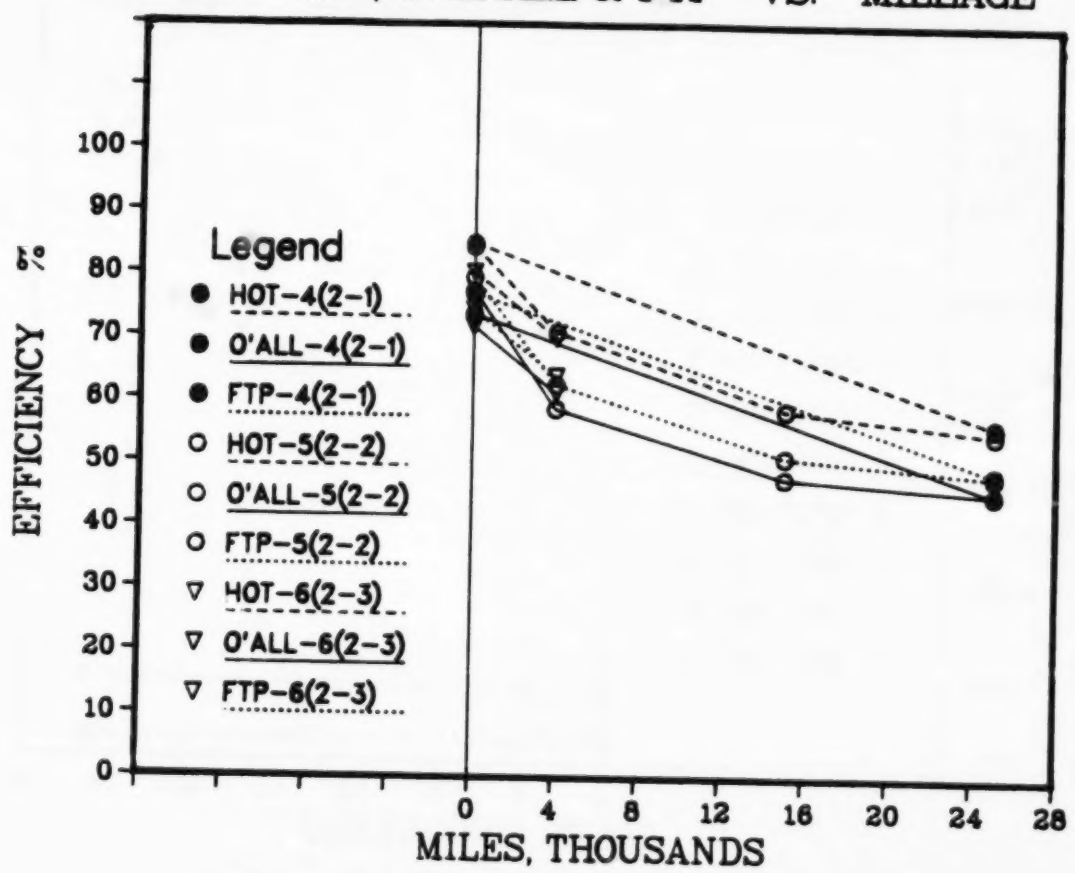

ENGINE-OUT AND TAILPIPE HC
CATALYST #5(2-2) MILES: 25 K
10% T, SEC 92.6
T50* T, SEC 125.5
50% T, SEC --------
HOT EFF % 54.94
OVERALL EFF % 45.40
FTP EFF % 48.17
HC % ENGINE OUT
% DISTANCE
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00


ENGINE-OUT AND TAILPIPE CO
CATALYST #5(2-2) MILES: 25 K
10% T, SEC 28.8
T50* T, SEC 122.8
50% T, SEC 1083.7
HOT EFF % 70.30
OVERALL EFF % 52.80
FTP EFF % 57.41
CO % ENGINE OUT
% DISTANCE
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

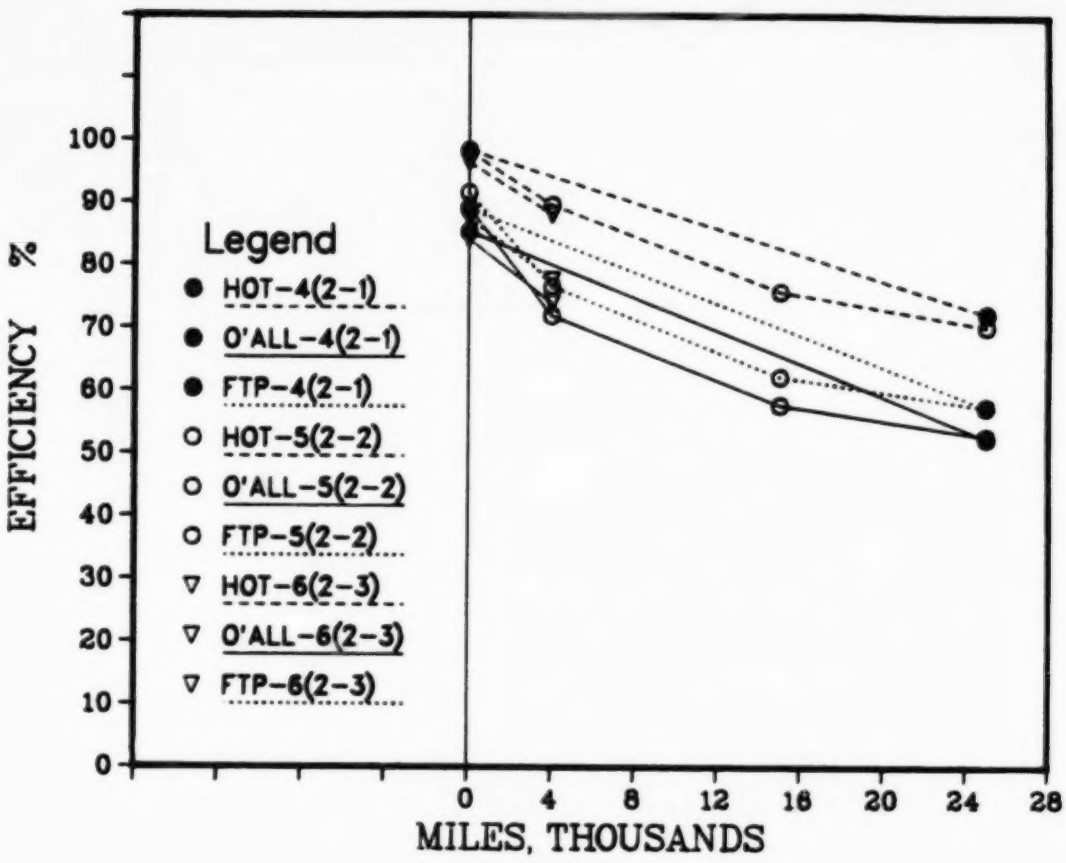

SUMMARY OF CATALYST PERFORMANCE
CATALYSTS 4(2-1), 5(2-2) & 6(2-3)
HC 10% T, T50* & 50% T VS. MILEAGE
TIME IN SECONDS
700
600
500
400
300
200
100
0
Legend
10%T-4(2-1)
T50*-4(2-1)
50%T-4(2-1)
10%T-5(2-2)
T50*-5(2-2)
50%T-5(2-2)
10%T-6(2-3)
T50*-6(2-3)
50%T-6(2-3)
0
4
8
12
16
20
24
28
MILES, THOUSANDS


SUMMARY OF CATALYST PERFORMANCE
CATALYSTS 4(2-1), 5(2-2) & 6(2-3)
CO: 10% T, T50* & 50% T VS. MILEAGE
TIME IN SECONDS
1200
1050
900
750
600
450
300
150
0
Legend
10%T-4(2-1)
T50*-4(2-1)
50%T-4(2-1)
10%T-5(2-2)
T50*-5(2-2)
50%T-5(2-2)
10%T-6(2-3)
T50*-6(2-3)
50%T-6(2-3)
0
4
8
12
16
20
24
28
MILES, THOUSANDS

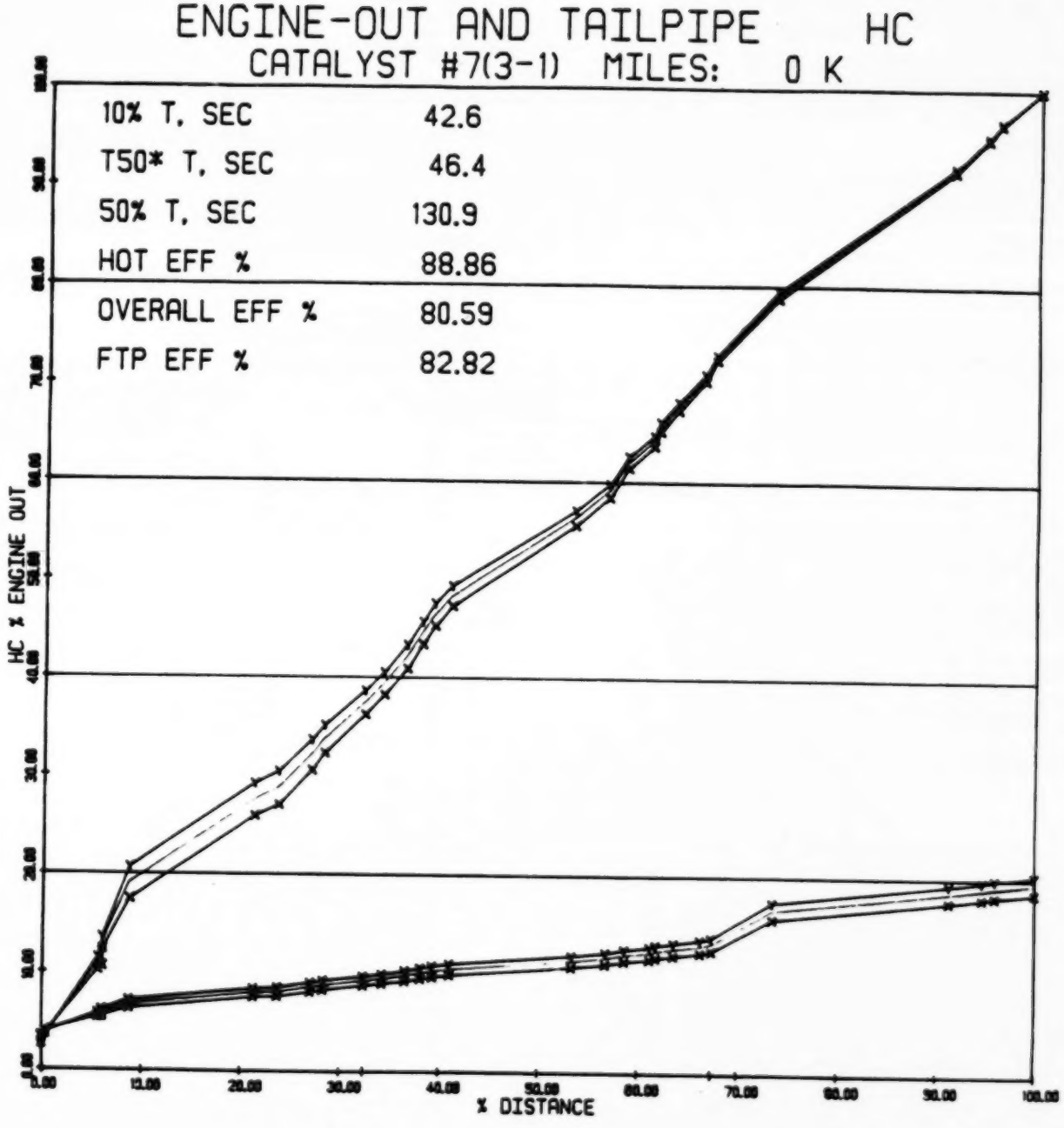
SUMMARY OF CATALYST PERFORMANCE
CATALYSTS 4(2-1), 5(2-2) & 6(2-3)
HC: HOT, OVERALL & FTP VS. MILEAGE



SUMMARY OF CATALYST PERFORMANCE
CATALYSTS 4(2-1), 5(2-2) & 6(2-3)
CO: HOT, OVERALL & FTP VS. MILEAGE



Brown Catalyst Data



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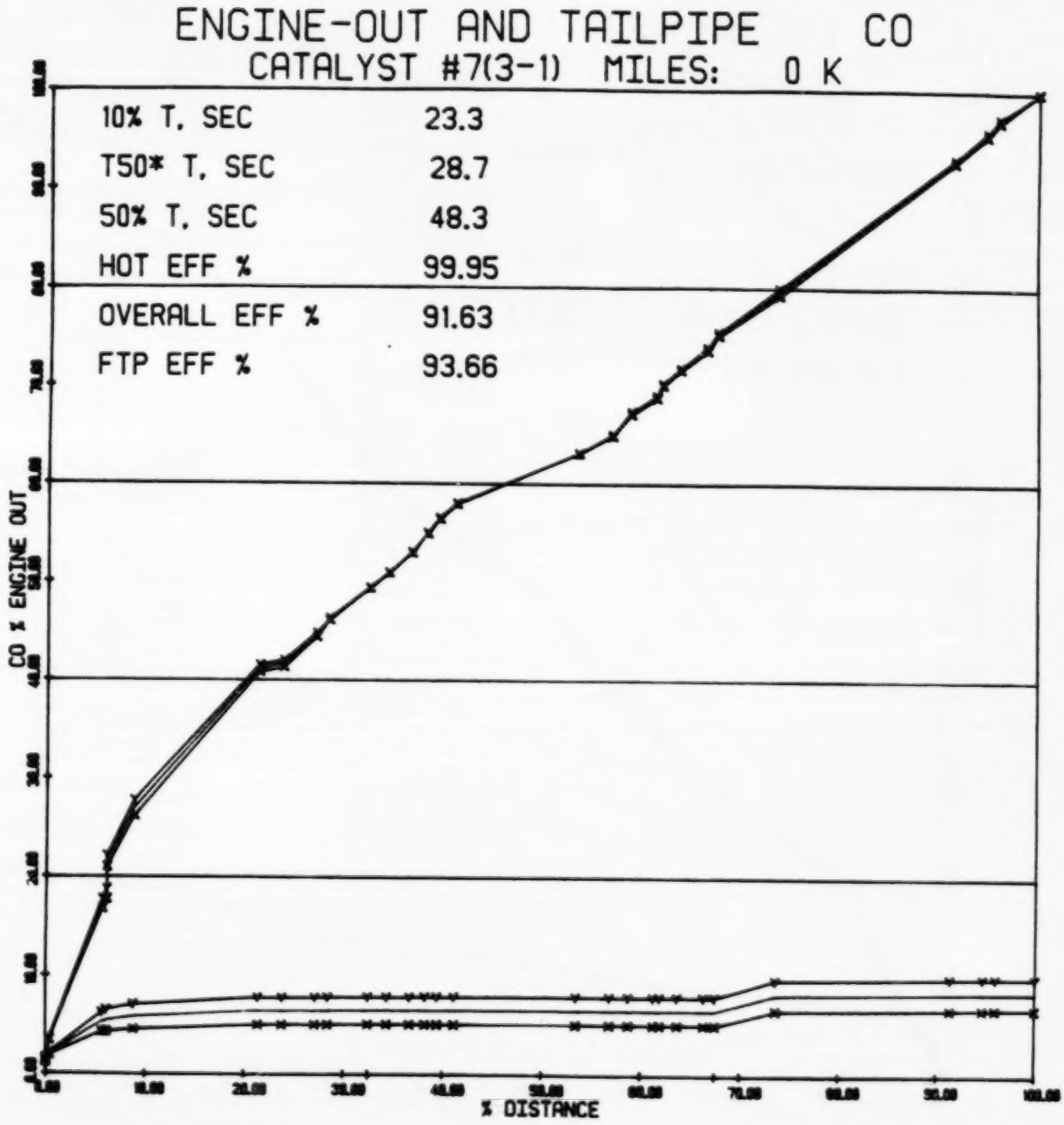
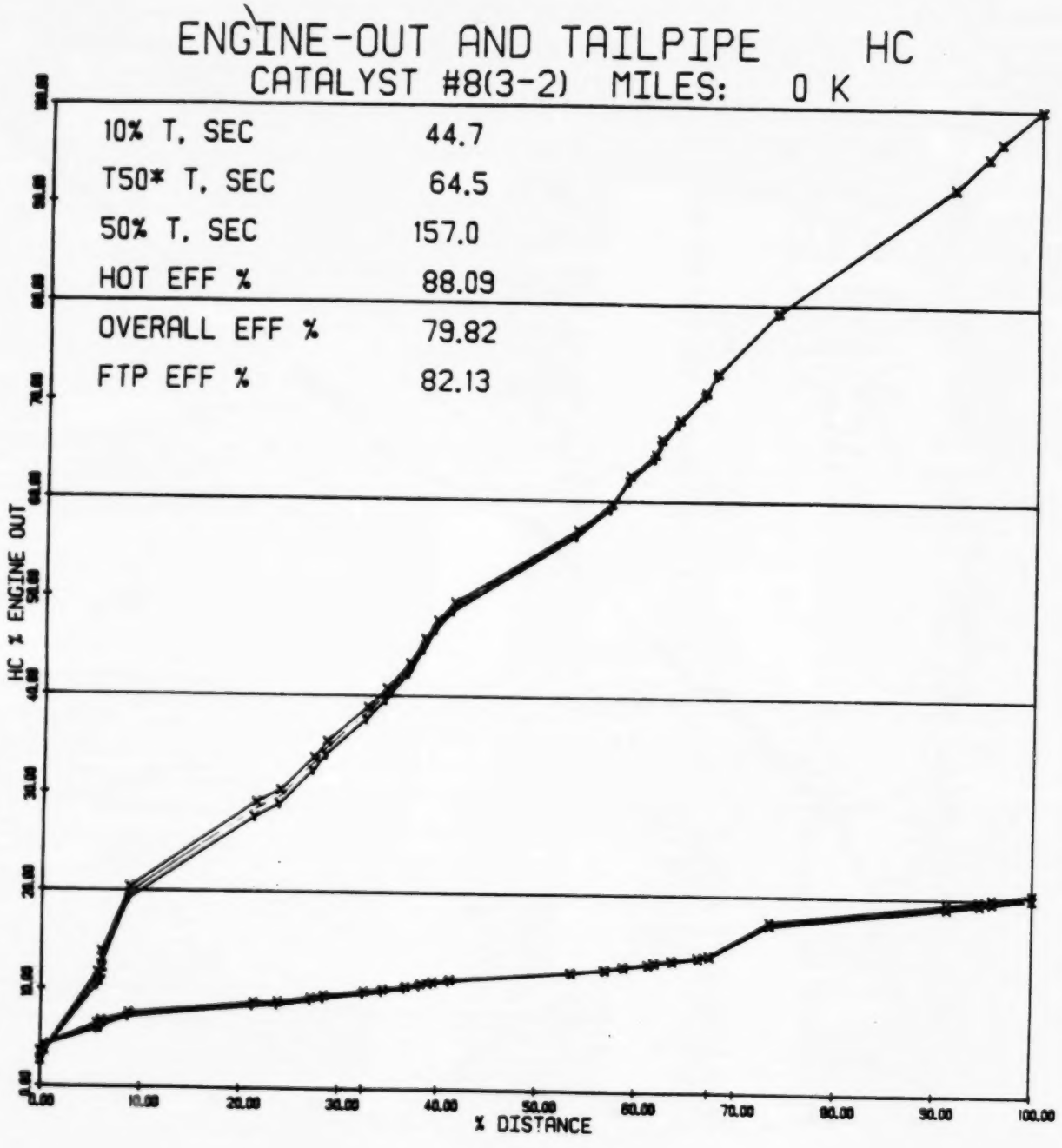
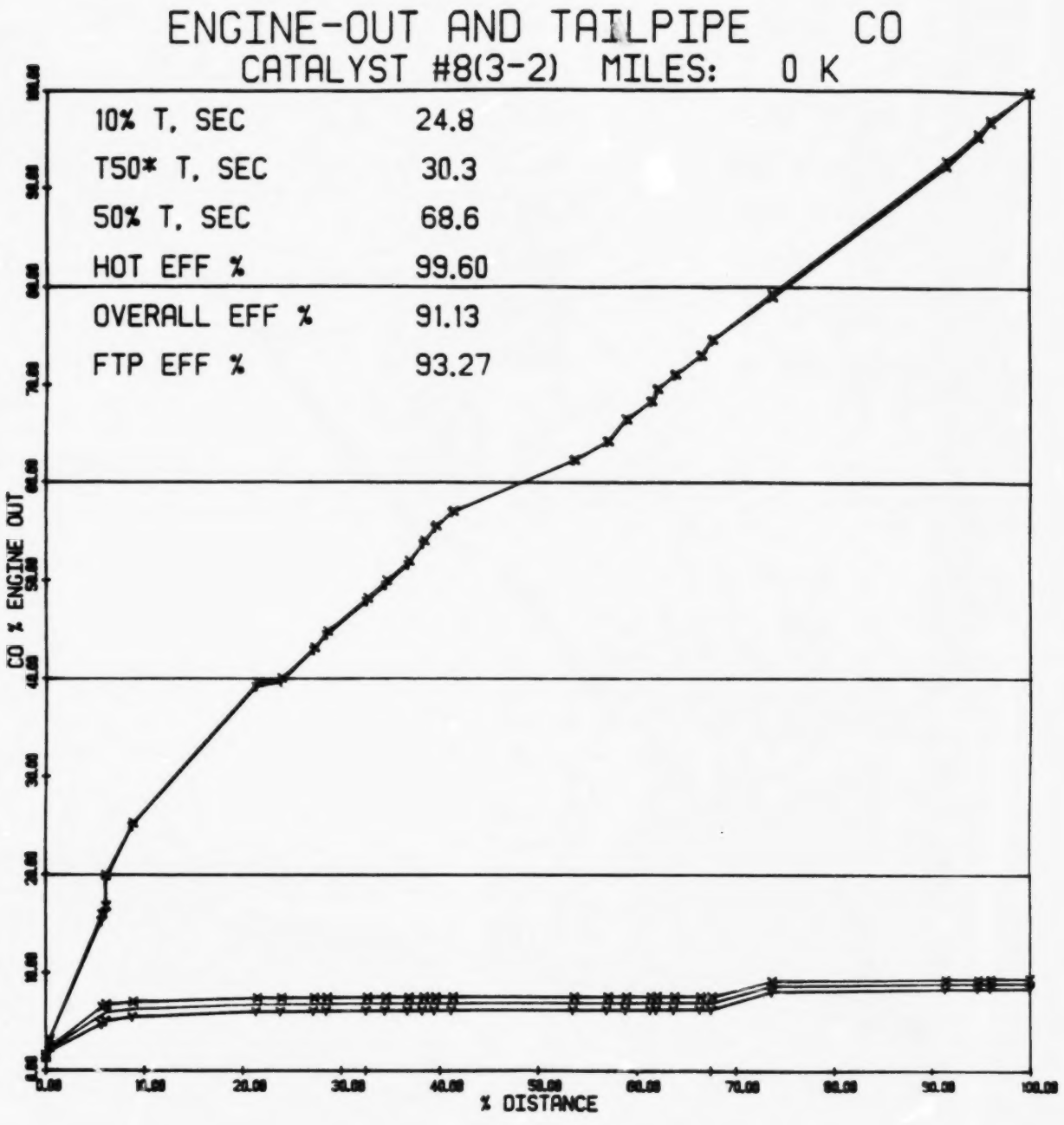
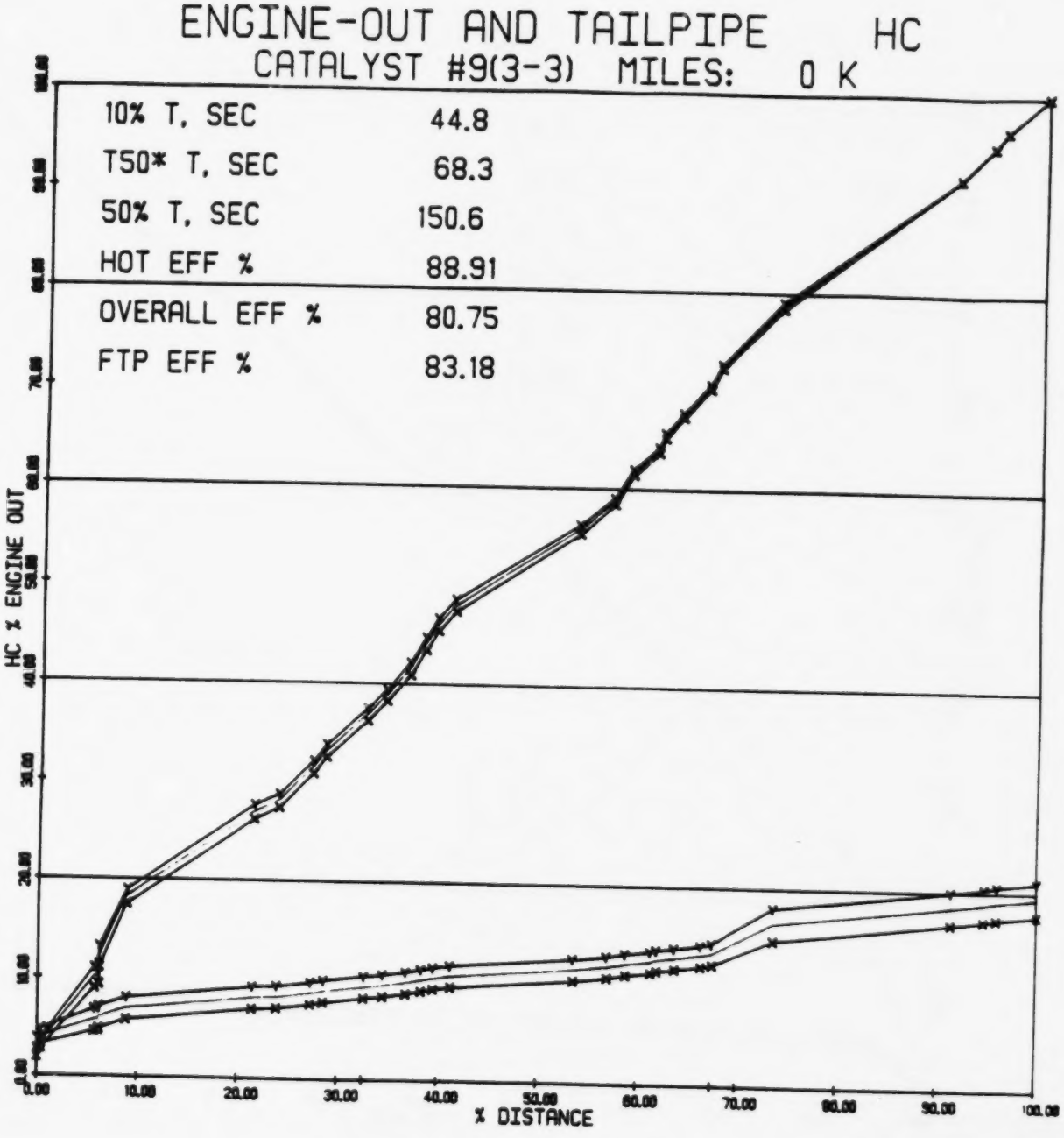
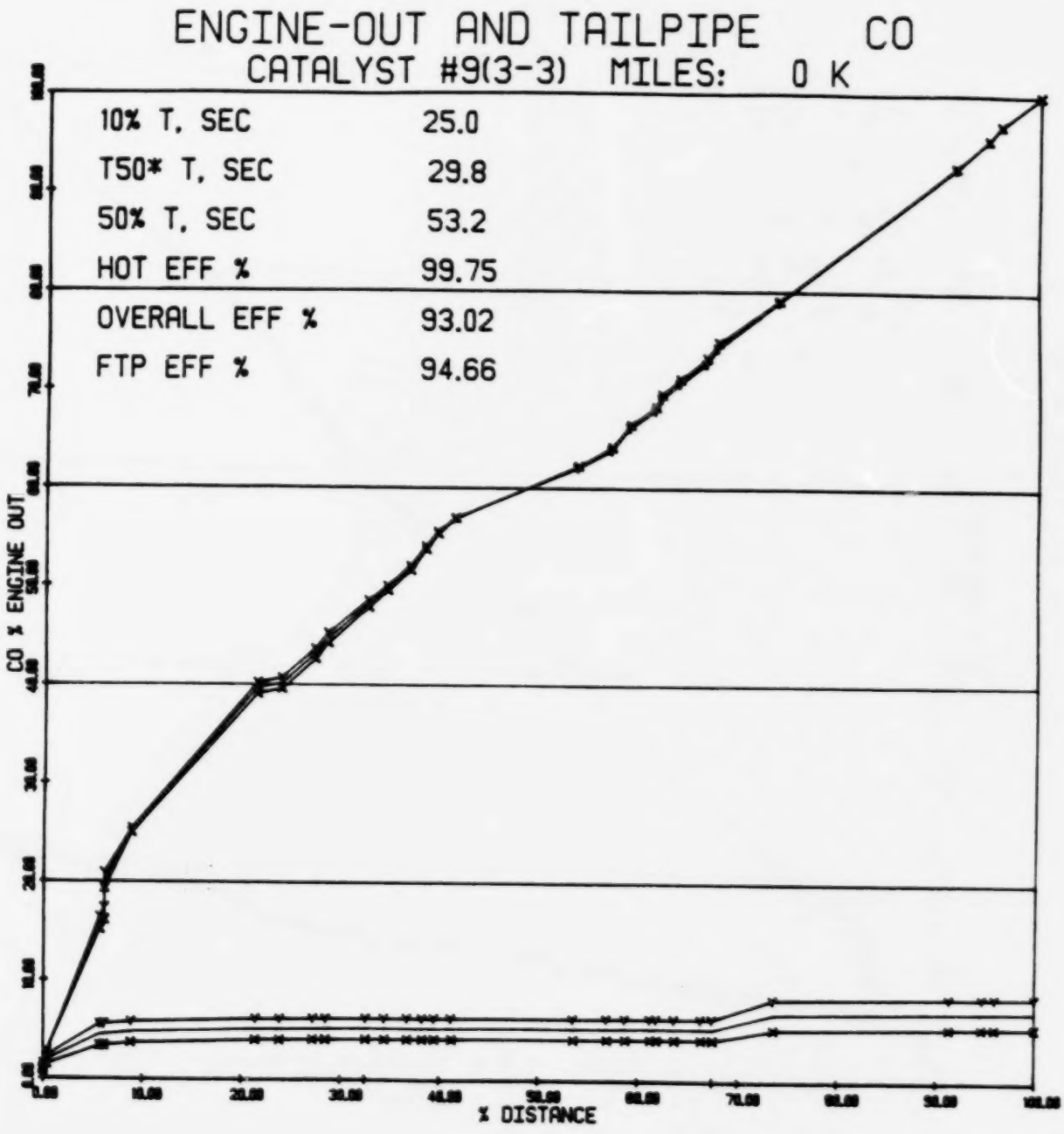
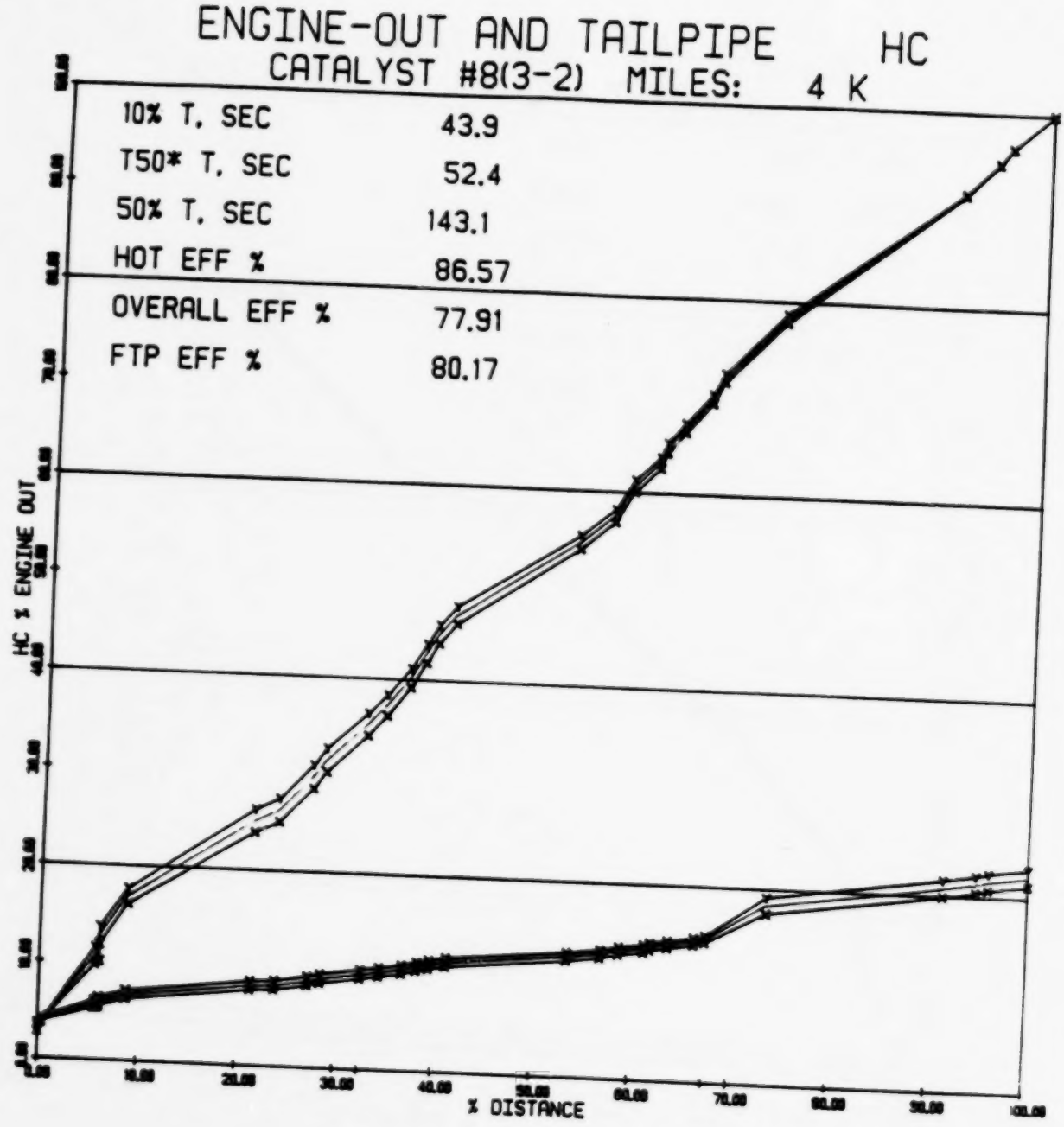

ENGINE-OUT AND TAILPIPE CO
CATALYST #7(3-1) MILES: 0 K
10% T, SEC 23.3
T50* T, SEC 28.7
50% T, SEC 48.3
HOT EFF % 99.95
OVERALL EFF % 91.63
FTP EFF % 93.66
CO % ENGINE OUT
% DISTANCE

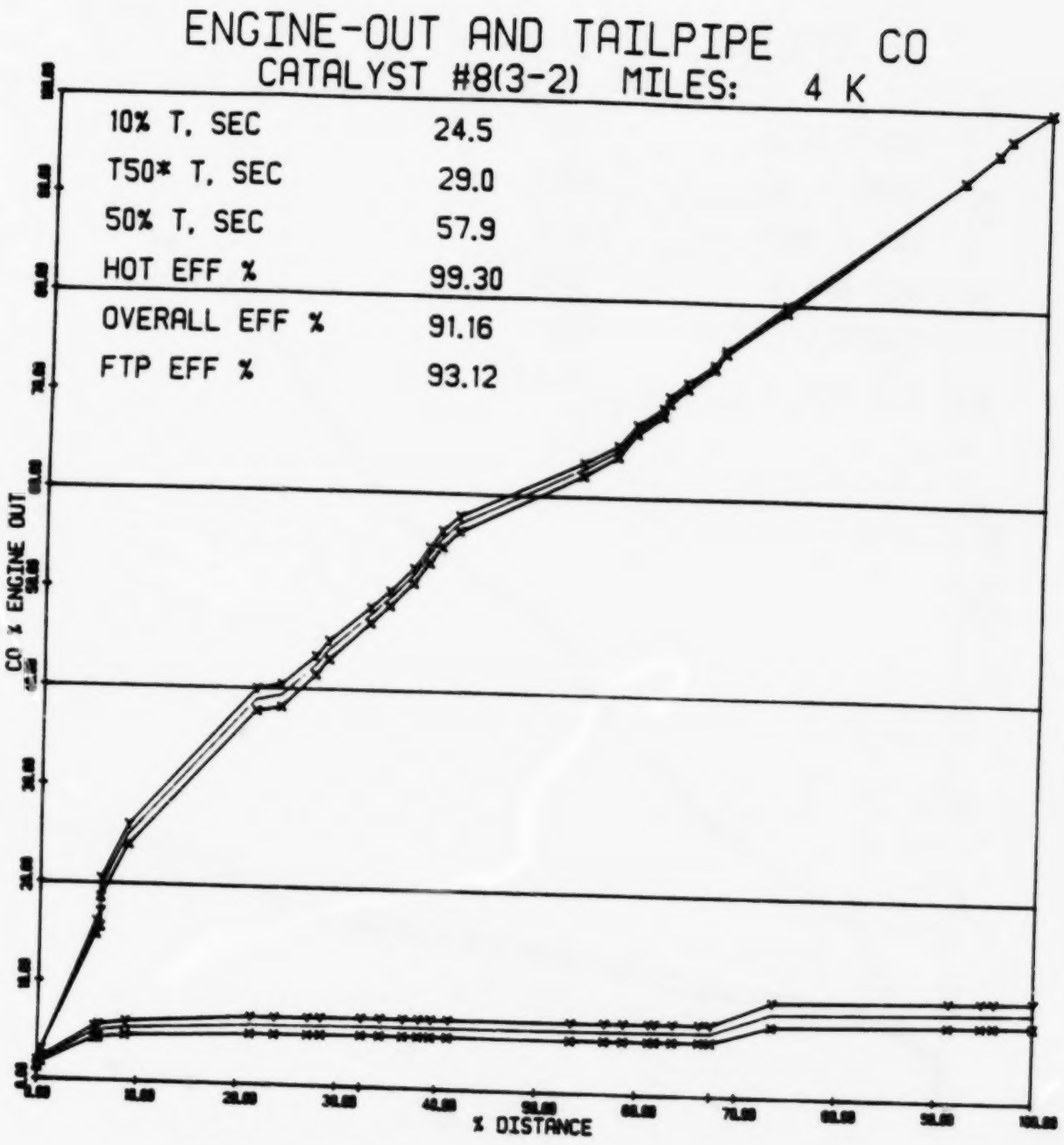

ENGINE-OUT AND TAILPIPE HC
CATALYST #8(3-2) MILES: 0 K
10% T, SEC 44.7
T50* T, SEC 64.5
50% T, SEC 157.0
HOT EFF % 88.09
OVERALL EFF % 79.82
FTP EFF % 82.13
HC % ENGINE OUT
% DISTANCE
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

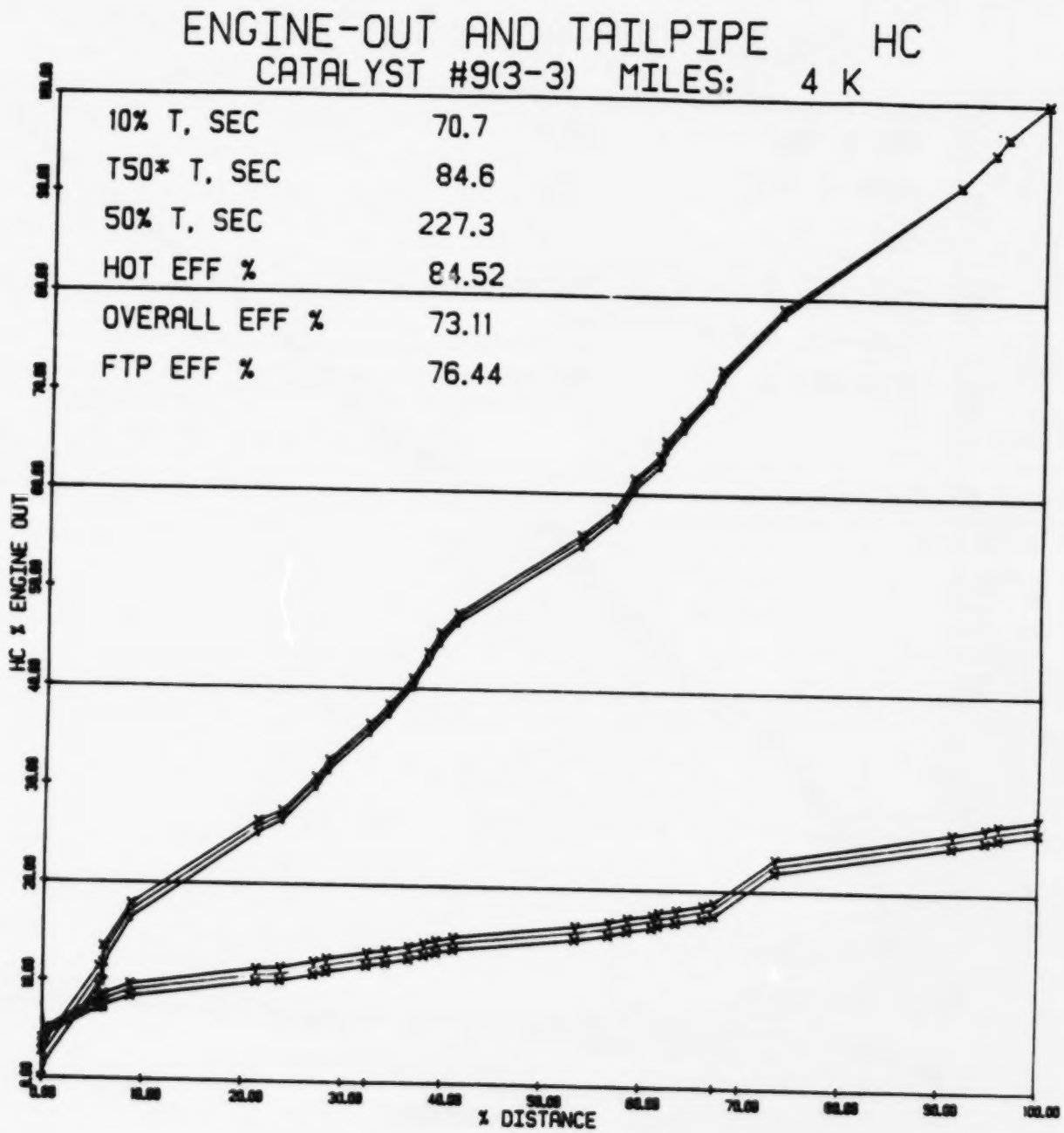

ENGINE-OUT AND TAILPIPE CO
CATALYST #8(3-2) MILES: 0 K
10% T, SEC 24.8
T50* T, SEC 30.3
50% T, SEC 68.6
HOT EFF % 99.60
OVERALL EFF % 91.13
FTP EFF % 93.27
CO % ENGINE OUT
% DISTANCE

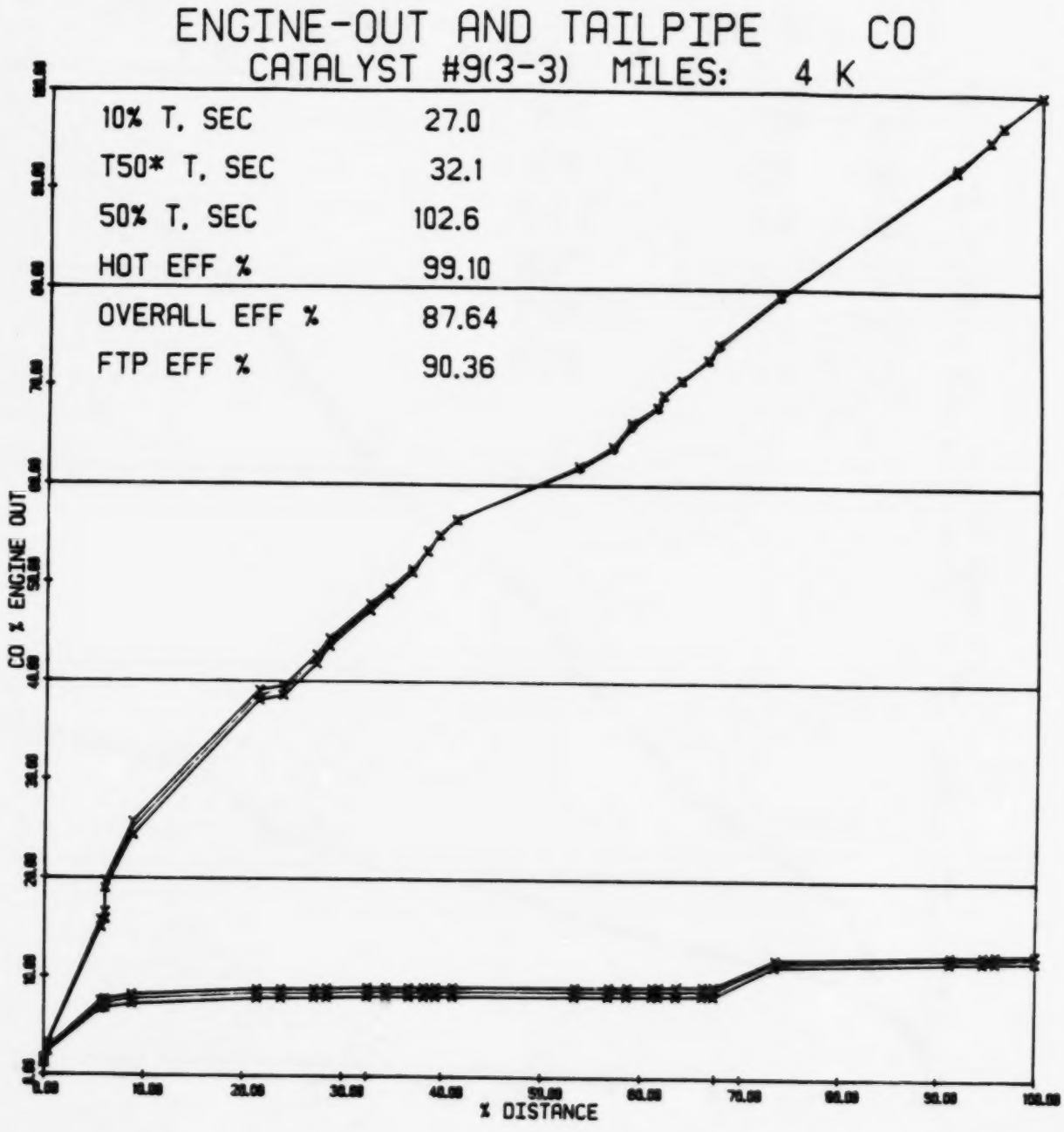

ENGINE-OUT AND TAILPIPE HC
CATALYST #9(3-3) MILES: 0 K
10% T, SEC 44.8
T50* T, SEC 68.3
50% T, SEC 150.6
HOT EFF % 88.91
OVERALL EFF % 80.75
FTP EFF % 83.18
HC % ENGINE OUT
% DISTANCE
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

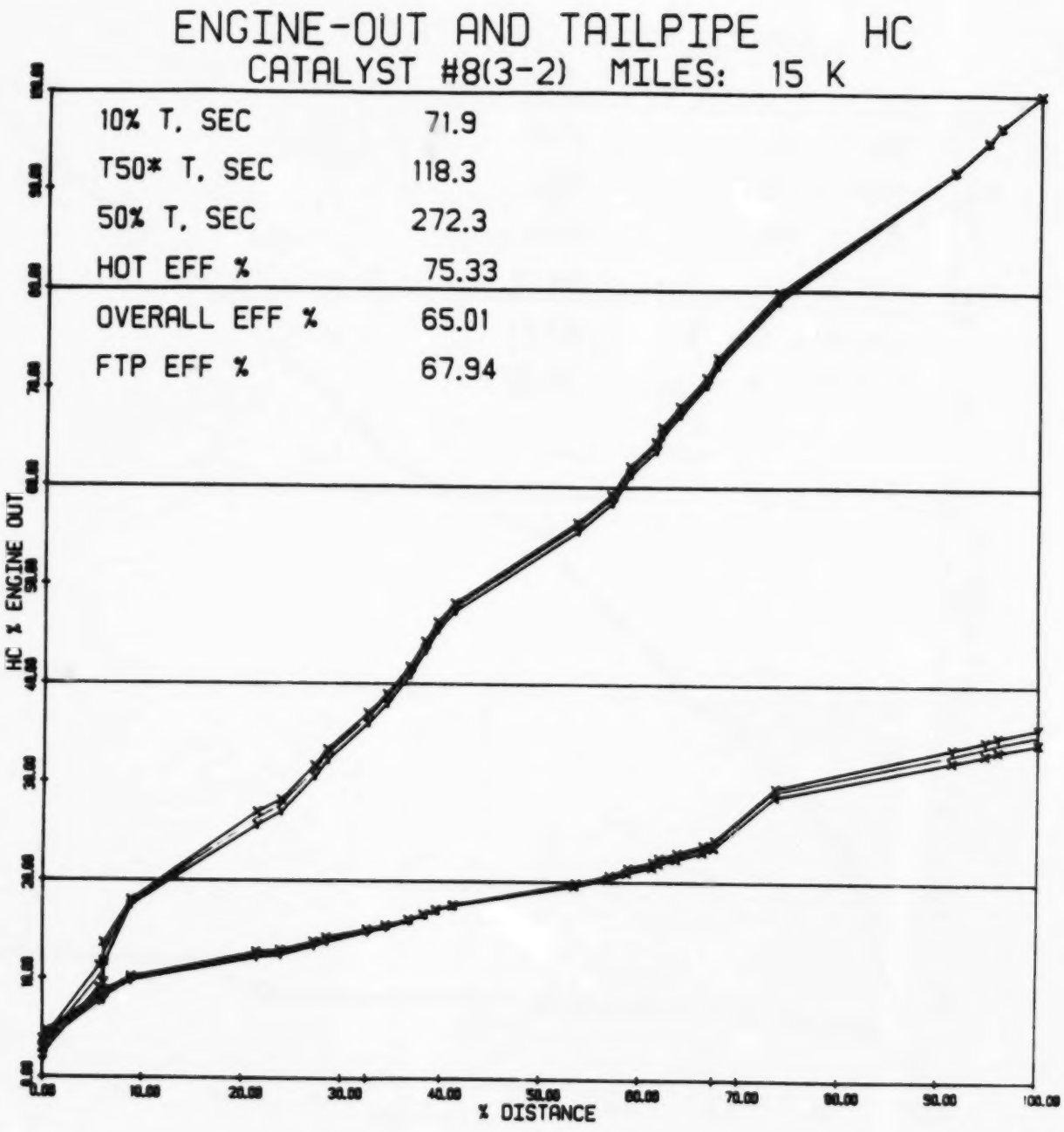

ENGINE-OUT AND TAILPIPE CO
CATALYST #9(3-3) MILES: 0 K
10% T, SEC 25.0
T50* T, SEC 29.8
50% T, SEC 53.2
HOT EFF % 99.75
OVERALL EFF % 93.02
FTP EFF % 94.66
CO % ENGINE OUT
% DISTANCE

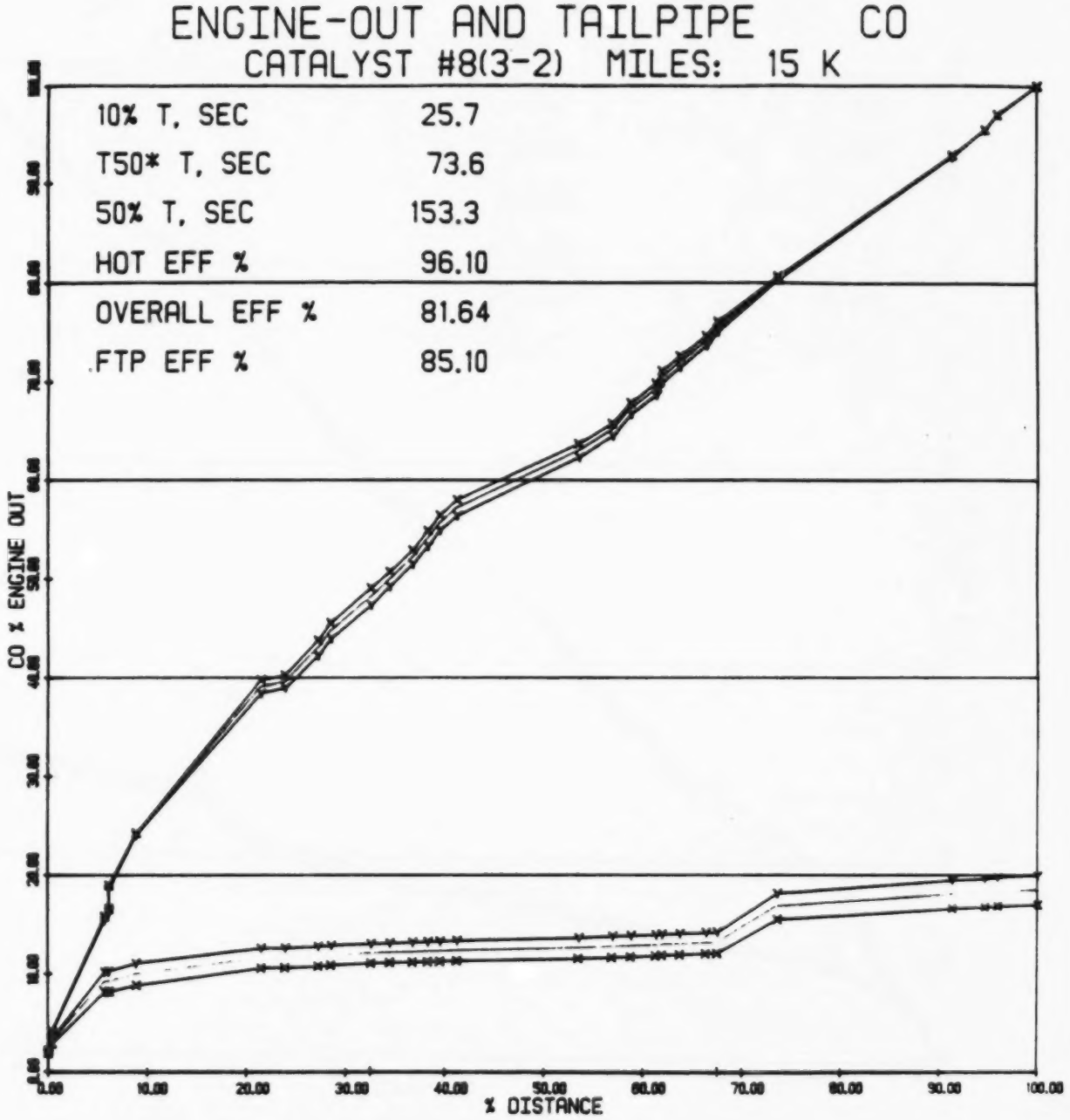

ENGINE-OUT AND TAILPIPE HC
CATALYST #8(3-2) MILES: 4 K
10% T. SEC 43.9
T50* T. SEC 52.4
50% T. SEC 143.1
HOT EFF % 86.57
OVERALL EFF % 77.91
FTP EFF % 80.17
HC % ENGINE OUT
% DISTANCE

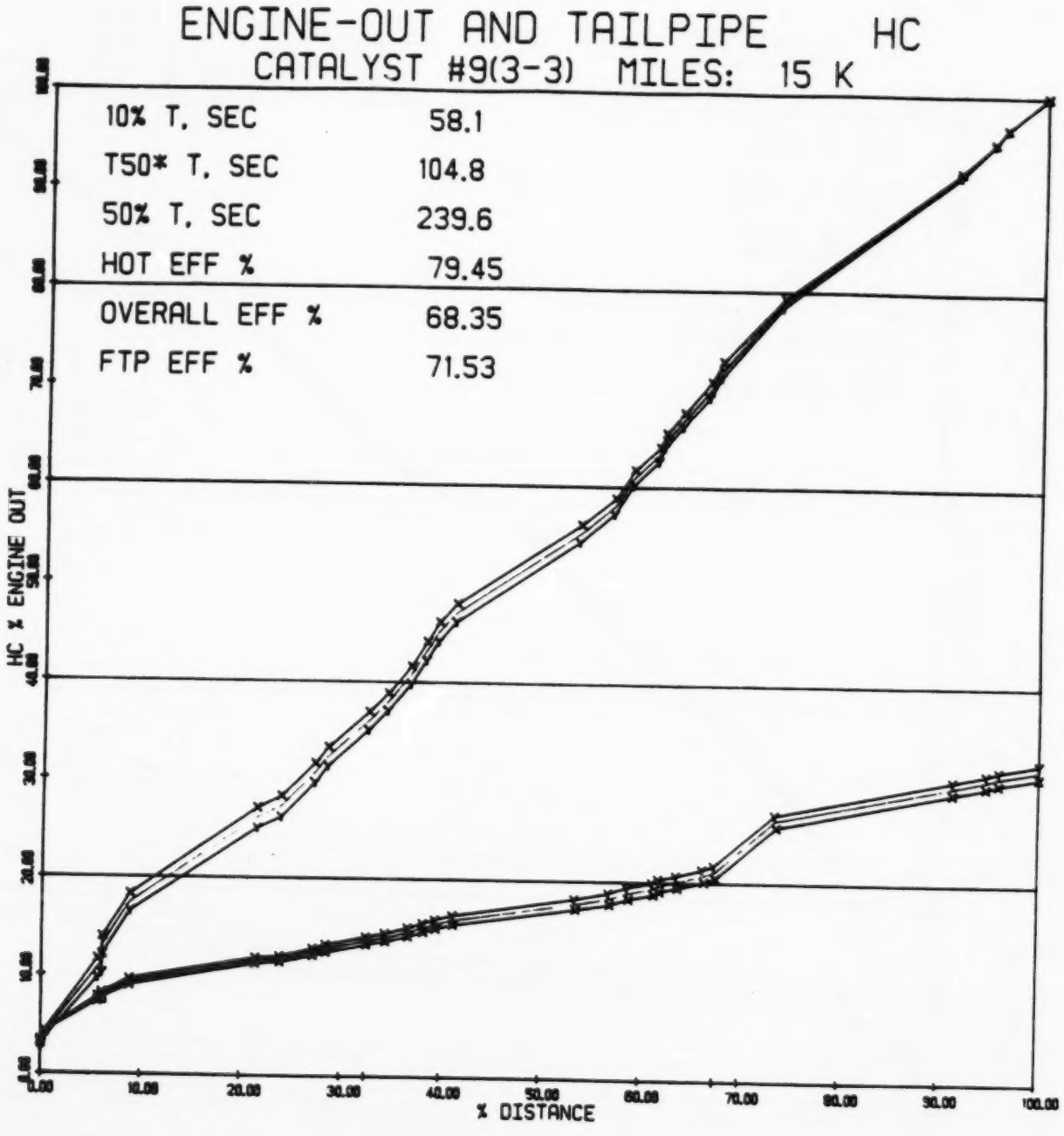

ENGINE-OUT AND TAILPIPE CO
CATALYST #8(3-2) MILES: 4 K
10% T, SEC 24.5
T50* T, SEC 29.0
50% T, SEC 57.9
HOT EFF % 99.30
OVERALL EFF % 91.16
FTP EFF % 93.12
CO % ENGINE OUT
% DISTANCE

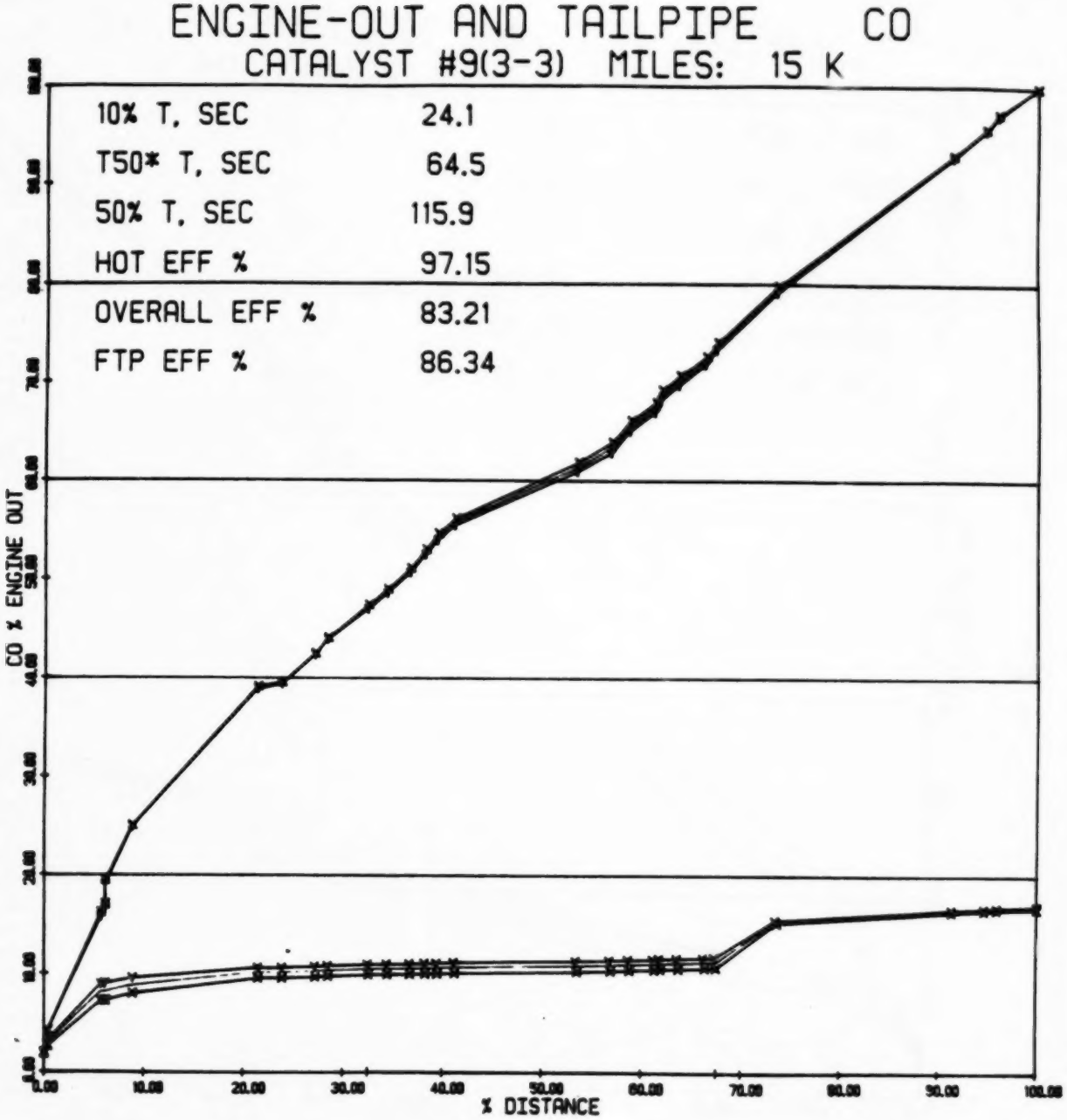

ENGINE-OUT AND TAILPIPE HC
CATALYST #9(3-3) MILES: 4 K
10% T, SEC 70.7
T50* T, SEC 84.6
50% T, SEC 227.3
HOT EFF % 84.52
OVERALL EFF % 73.11
FTP EFF % 76.44
HC X ENGINE OUT
% DISTANCE

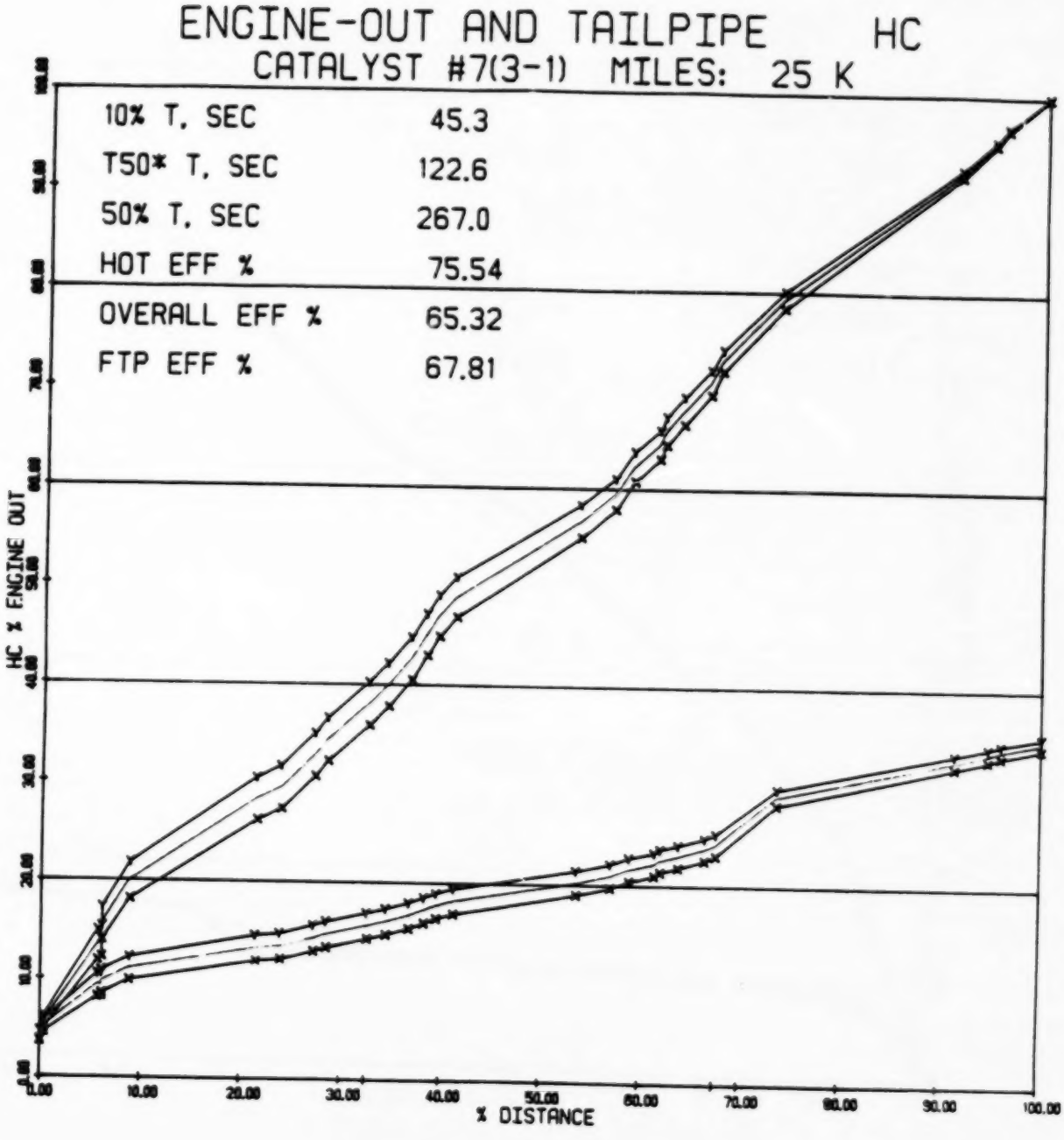

ENGINE-OUT AND TAILPIPE CO
CATALYST #9(3-3) MILES: 4 K
10% T, SEC 27.0
T50* T, SEC 32.1
50% T, SEC 102.6
HOT EFF % 99.10
OVERALL EFF % 87.64
FTP EFF % 90.36
CO % ENGINE OUT
% DISTANCE

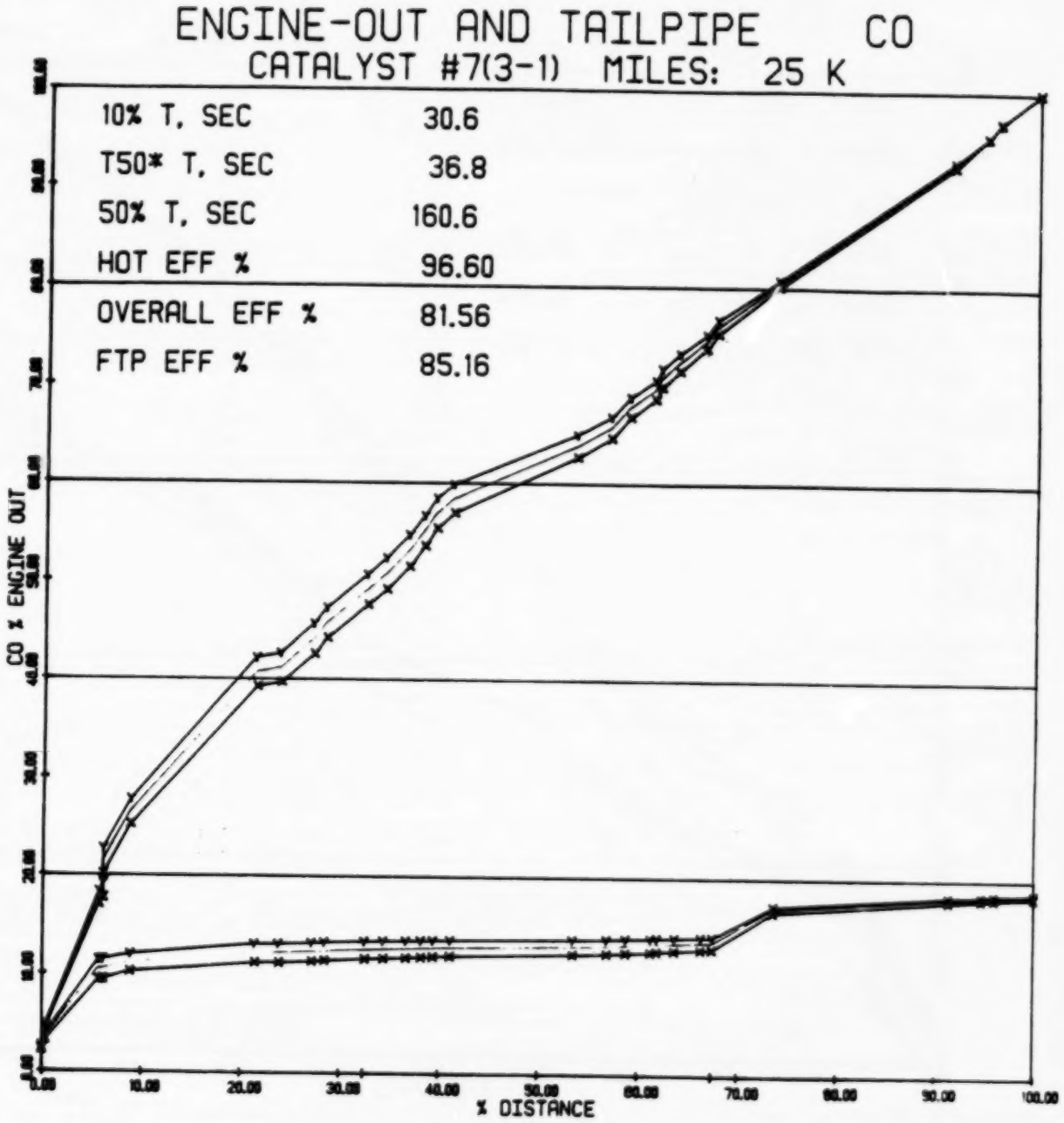

ENGINE-OUT AND TAILPIPE HC
CATALYST #8(3-2) MILES: 15 K
10% T, SEC 71.9
T50* T, SEC 118.3
50% T, SEC 272.3
HOT EFF % 75.33
OVERALL EFF % 65.01
FTP EFF % 67.94
HC % ENGINE OUT
% DISTANCE

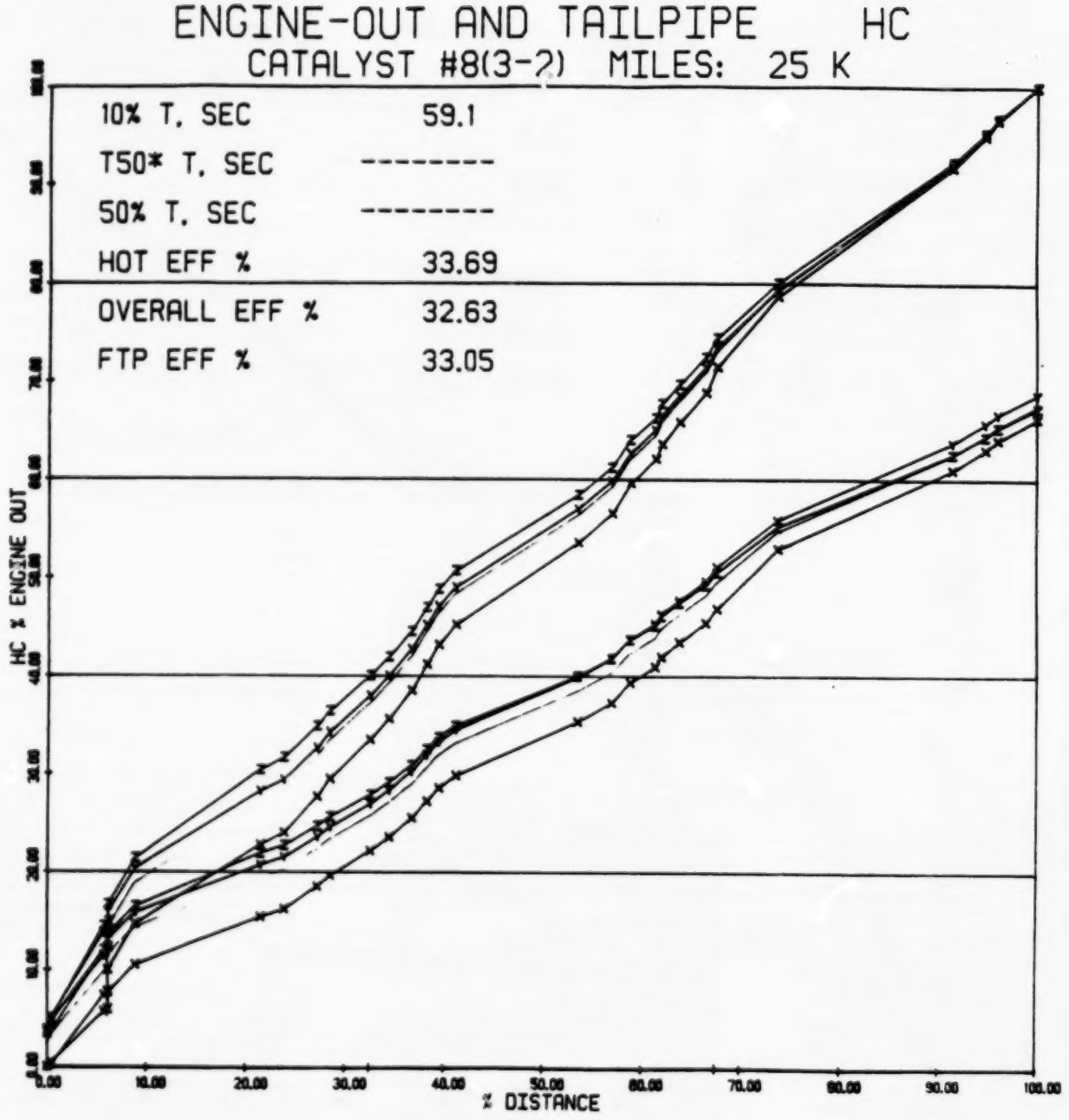

ENGINE-OUT AND TAILPIPE CO
CATALYST #8(3-2) MILES: 15 K
10% T, SEC 25.7
T50* T, SEC 73.6
50% T, SEC 153.3
HOT EFF % 96.10
OVERALL EFF % 81.64
FTP EFF % 85.10
CO % ENGINE OUT
% DISTANCE
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

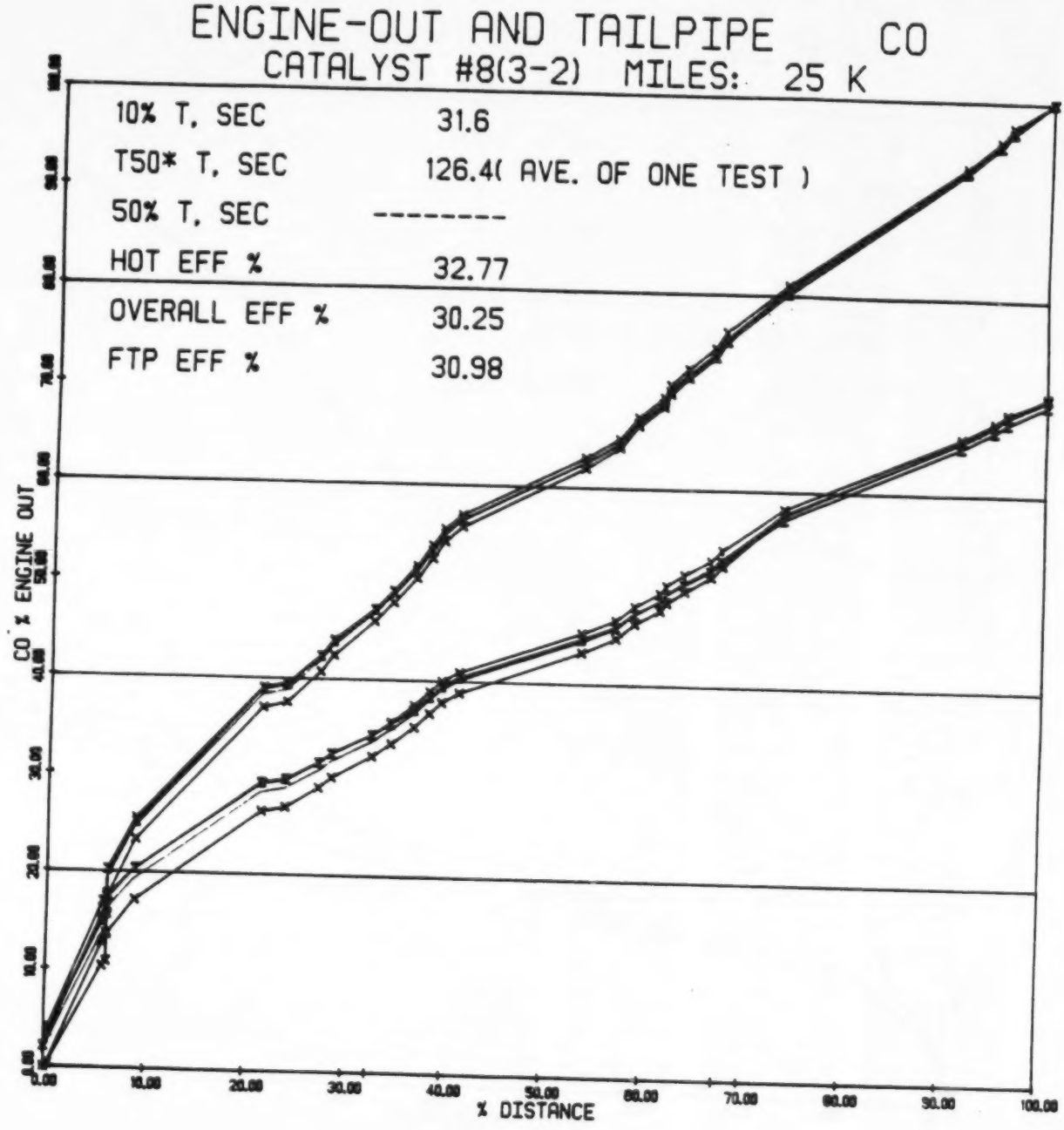

ENGINE-OUT AND TAILPIPE HC
CATALYST #9(3-3) MILES: 15 K
10% T. SEC 58.1
T50* T. SEC 104.8
50% T. SEC 239.6
HOT EFF % 79.45
OVERALL EFF % 68.35
FTP EFF % 71.53
HC % ENGINE OUT
% DISTANCE
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

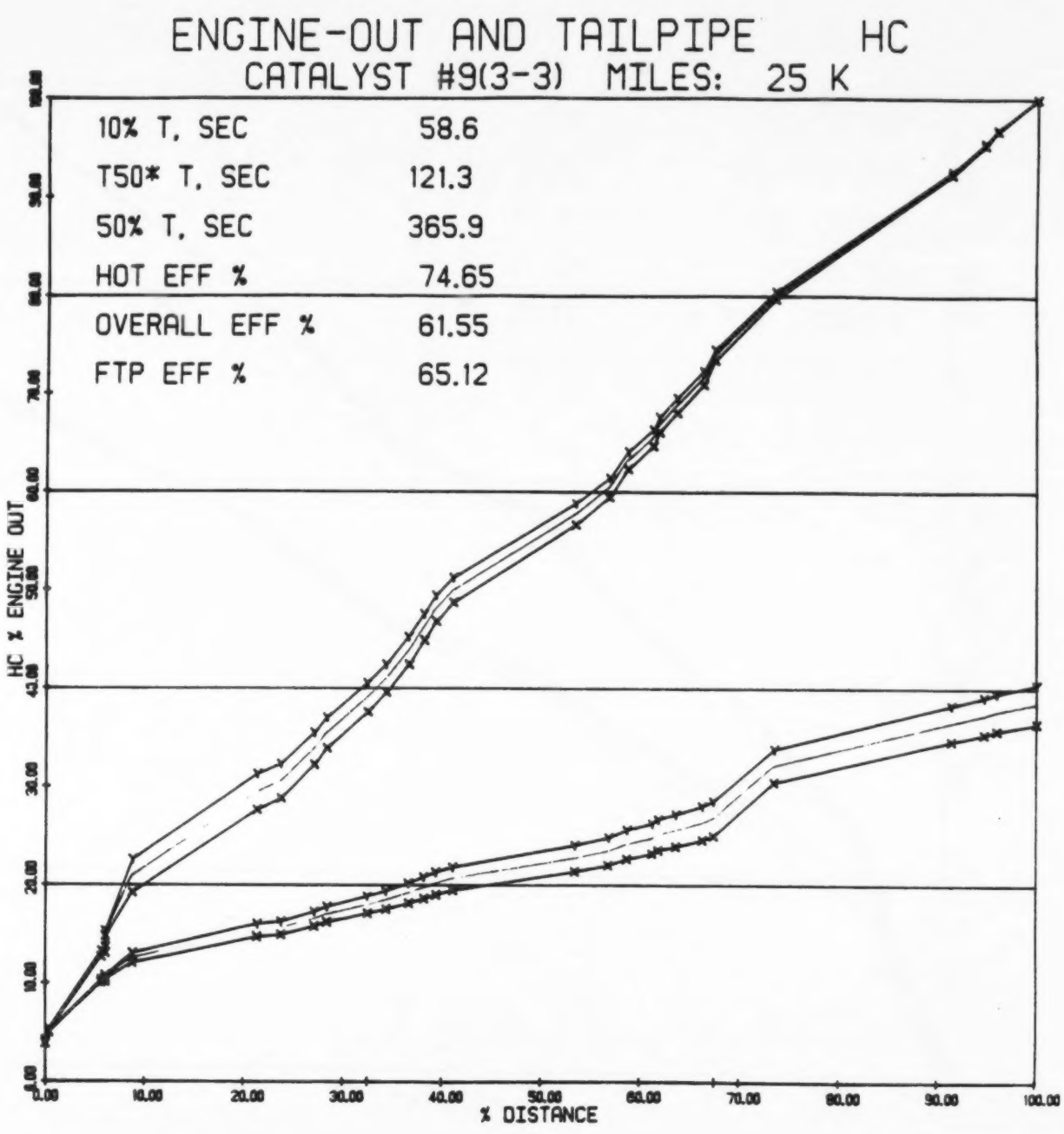

ENGINE-OUT AND TAILPIPE CO
CATALYST #9(3-3) MILES: 15 K
10% T, SEC 24.1
T50* T, SEC 64.5
50% T, SEC 115.9
HOT EFF % 97.15
OVERALL EFF % 83.21
FTP EFF % 86.34
CO % ENGINE OUT
% DISTANCE
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

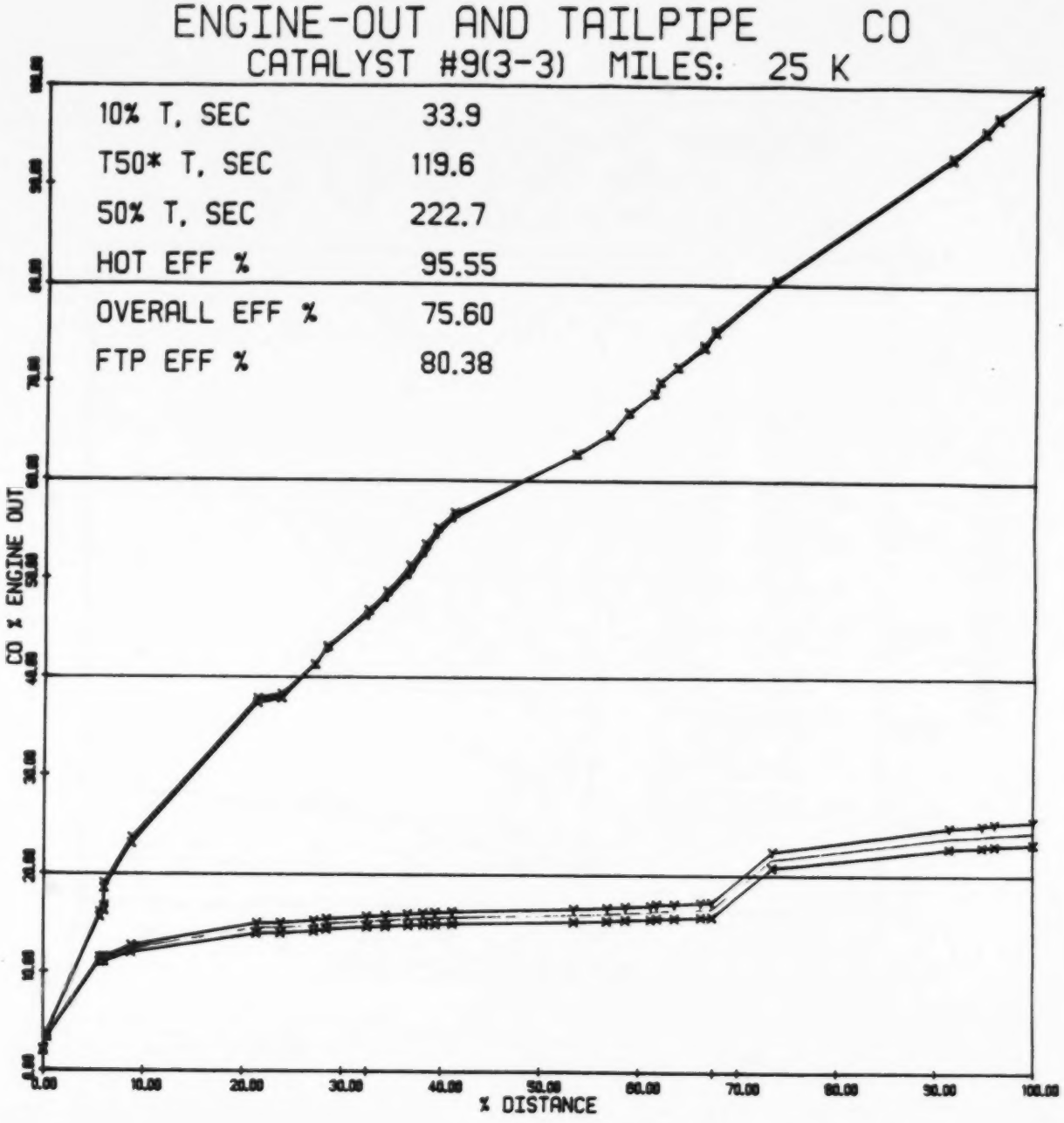

ENGINE-OUT AND TAILPIPE HC
CATALYST #7(3-1) MILES: 25 K
10% T. SEC 45.3
T50* T. SEC 122.6
50% T. SEC 267.0
HOT EFF % 75.54
OVERALL EFF % 65.32
FTP EFF % 67.81
HC % ENGINE OUT
% DISTANCE
1.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

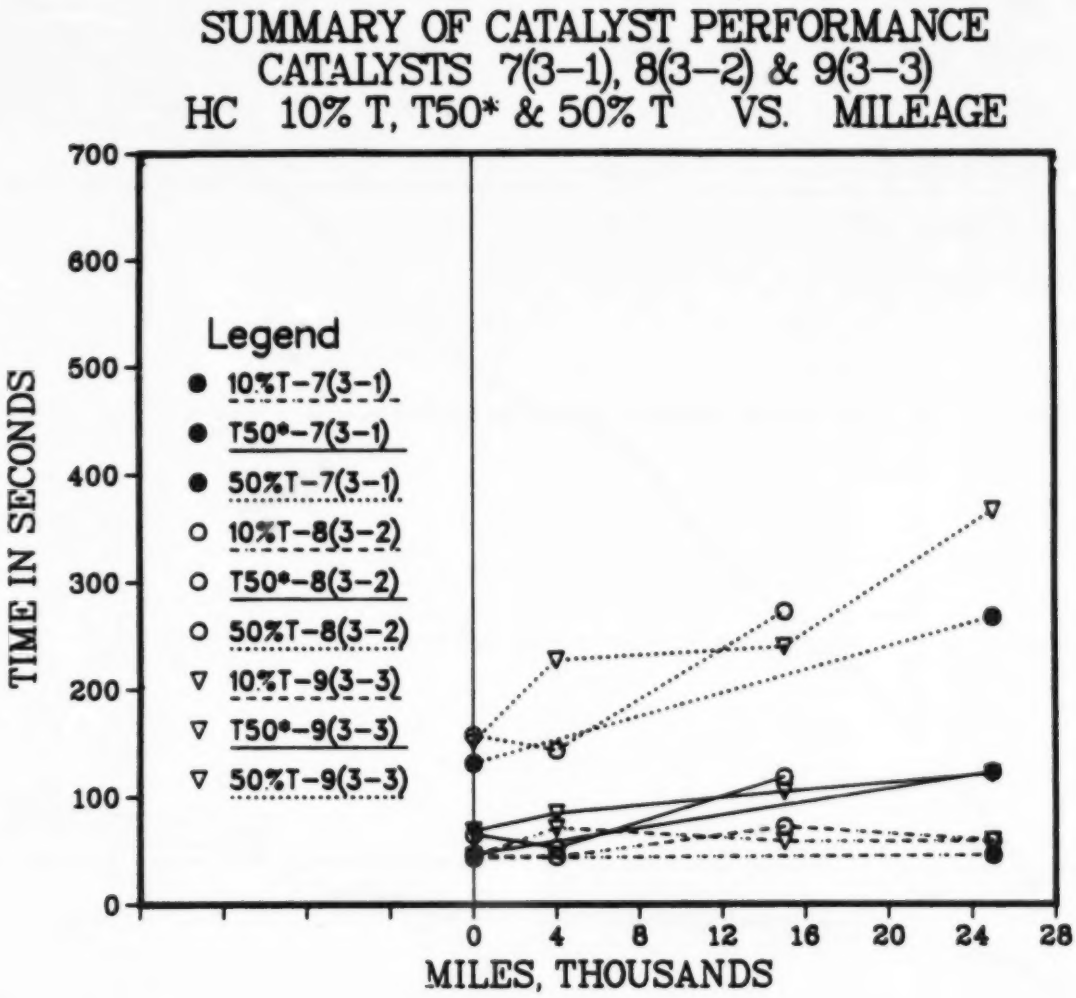

ENGINE-OUT AND TAILPIPE CO
CATALYST #7(3-1) MILES: 25 K
10% T, SEC 30.6
T50* T, SEC 36.8
50% T, SEC 160.6
HOT EFF % 96.60
OVERALL EFF % 81.56
FTP EFF % 85.16
CO % ENGINE OUT
% DISTANCE

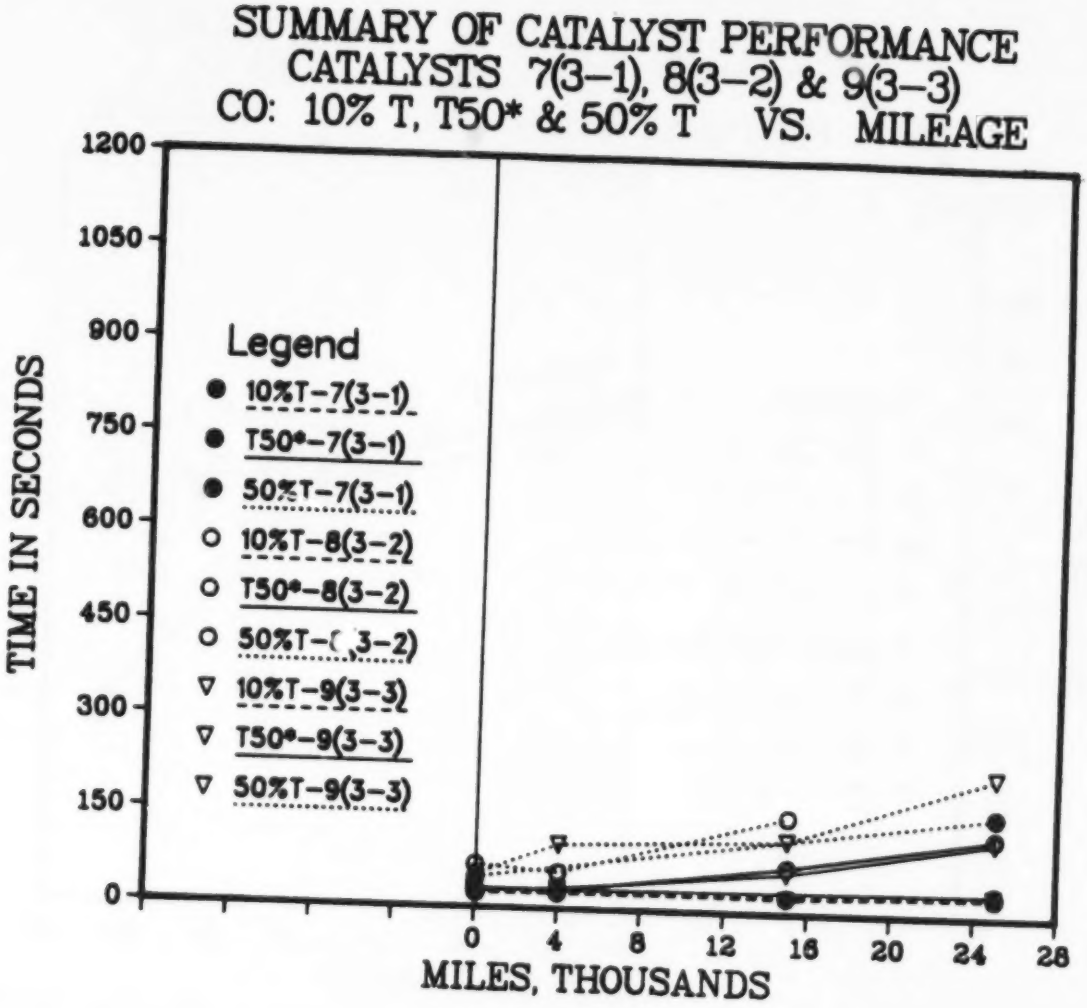

ENGINE-OUT AND TAILPIPE HC
CATALYST #8(3-2) MILES: 25 K
10% T, SEC 59.1
T50* T, SEC --------
50% T, SEC --------
HOT EFF % 33.69
OVERALL EFF % 32.63
FTP EFF % 33.05
HC % ENGINE OUT
% DISTANCE
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00


ENGINE-OUT AND TAILPIPE CO
CATALYST #8(3-2) MILES: 25 K
10% T, SEC 31.6
T50* T, SEC 126.4(AVE. OF ONE TEST)
50% T, SEC --------
HOT EFF % 32.77
OVERALL EFF % 30.25
FTP EFF % 30.98
CO % ENGINE OUT
% DISTANCE
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

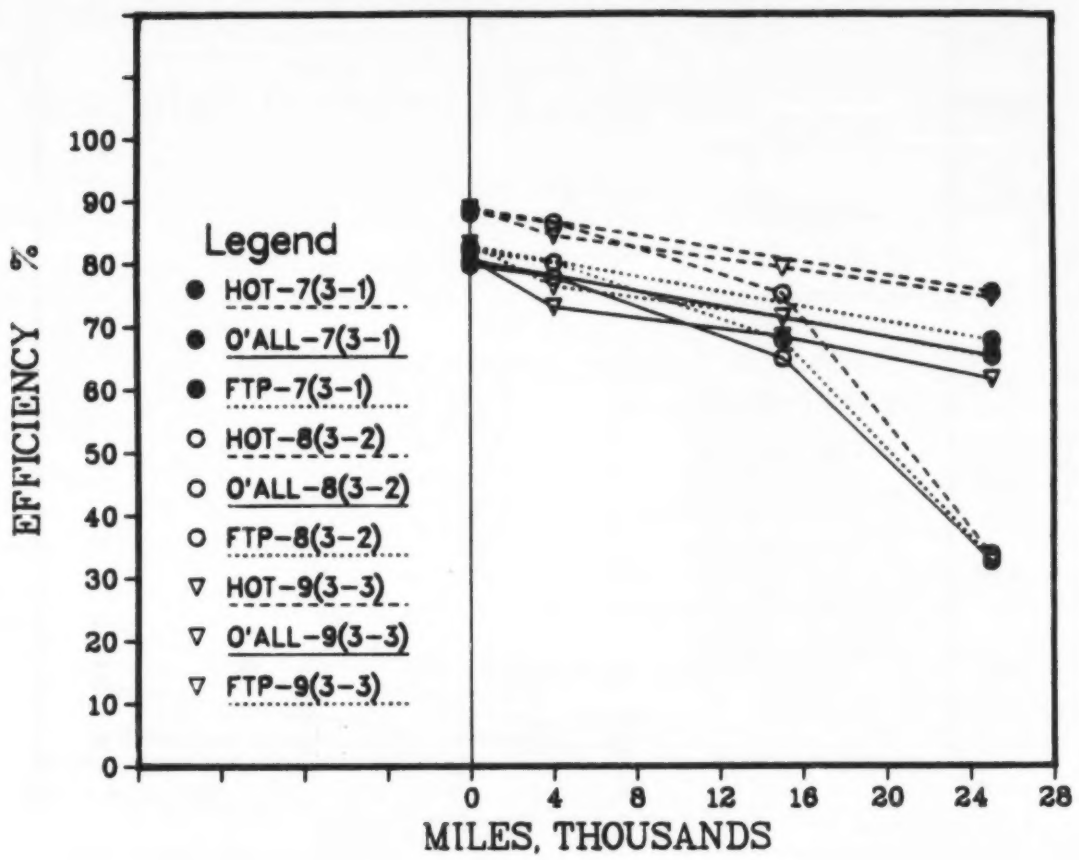

ENGINE-OUT AND TAILPIPE HC
CATALYST #9(3-3) MILES: 25 K
10% T, SEC 58.6
T50* T, SEC 121.3
50% T, SEC 365.9
HOT EFF % 74.65
OVERALL EFF % 61.55
FTP EFF % 65.12
HC % ENGINE OUT
% DISTANCE
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

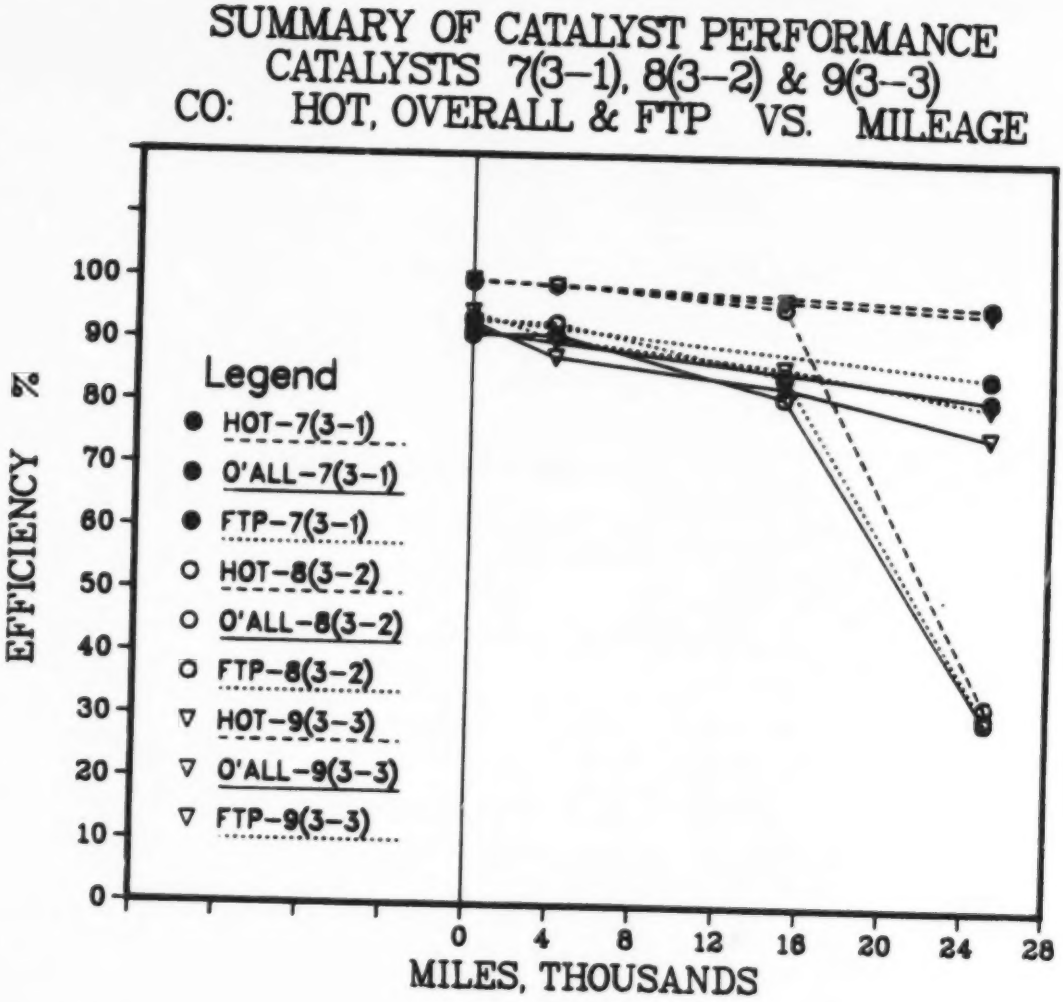

ENGINE-OUT AND TAILPIPE CO
CATALYST #9(3-3) MILES: 25 K
10% T, SEC 33.9
T50* T, SEC 119.6
50% T, SEC 222.7
HOT EFF % 95.55
OVERALL EFF % 75.60
FTP EFF % 80.38
CO % ENGINE OUT
% DISTANCE
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00


SUMMARY OF CATALYST PERFORMANCE
CATALYSTS 7(3-1), 8(3-2) & 9(3-3)
HC 10% T, T50* & 50% T VS. MILEAGE
TIME IN SECONDS
700
600
500
400
300
200
100
0
Legend
10%T-7(3-1)
T50*-7(3-1)
50%T-7(3-1)
10%T-8(3-2)
T50*-8(3-2)
50%T-8(3-2)
10%T-9(3-3)
T50*-9(3-3)
50%T-9(3-3)
0
4
8
12
16
20
24
28
MILES, THOUSANDS

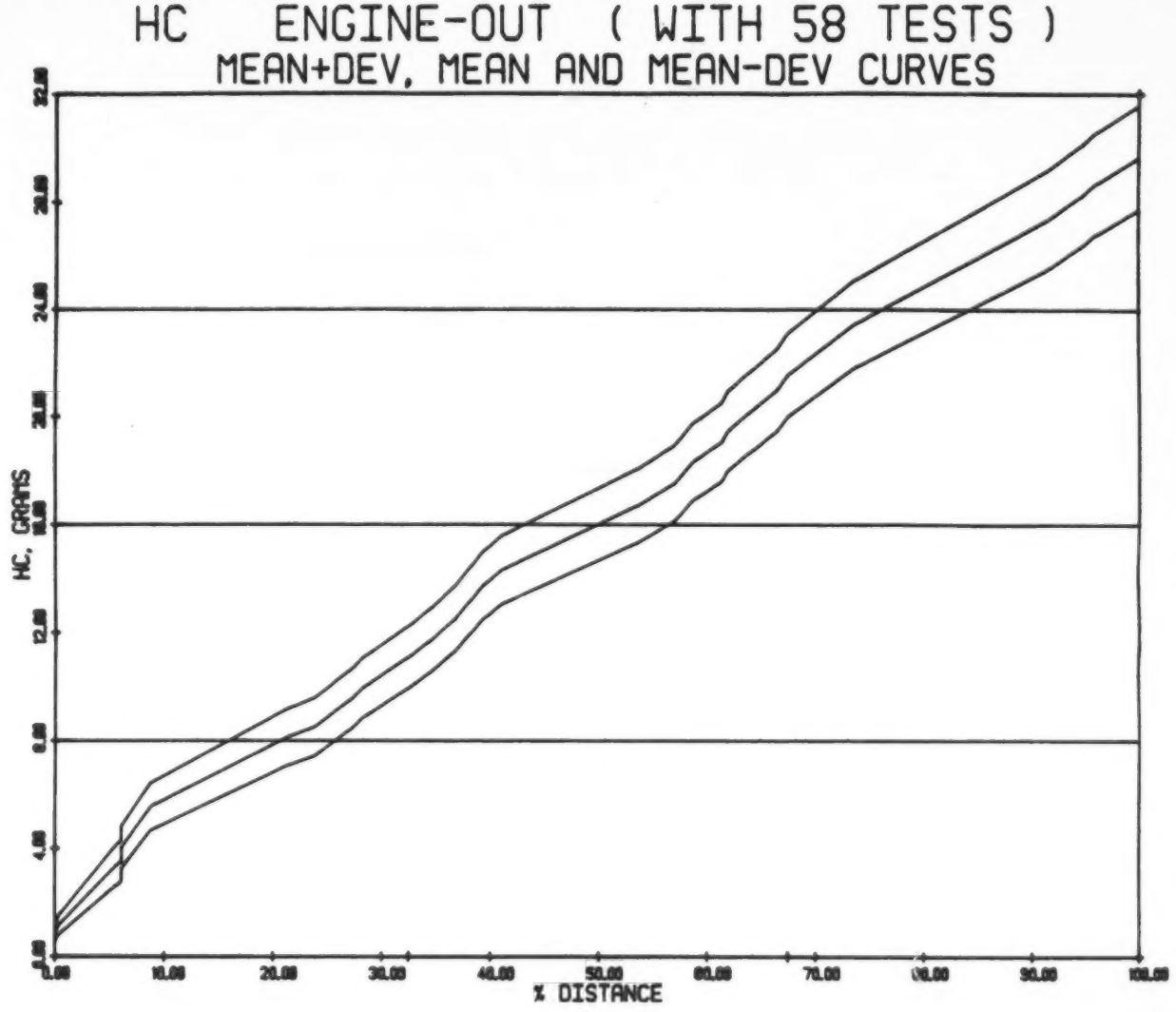

SUMMARY OF CATALYST PERFORMANCE
CATALYSTS 7(3-1), 8(3-2) & 9(3-3)
CO: 10% T, T50* & 50% T VS. MILEAGE
TIME IN SECONDS
1200
1050
900
750
600
450
300
150
0
Legend
10%T-7(3-1)
T50*-7(3-1)
50%T-7(3-1)
10%T-8(3-2)
T50*-8(3-2)
50%T-8(3-2)
10%T-9(3-3)
T50*-9(3-3)
50%T-9(3-3)
0
4
8
12
16
20
24
28
MILES, THOUSANDS

SUMMARY OF CATALYST PERFORMANCE
CATALYSTS 7(3–1), 8(3–2) & 9(3–3)
HC: HOT, OVERALL & FTP VS. MILEAGE




SUMMARY OF CATALYST PERFORMANCE
CATALYSTS 7(3–1), 8(3–2) & 9(3–3)
CO: HOT, OVERALL & FTP VS. MILEAGE
EFFICIENCY %
100
90
80
70
60
50
40
30
20
10
0
Legend
HOT–7(3–1)
O'ALL–7(3–1)
FTP–7(3–1)
HOT–8(3–2)
O'ALL–8(3–2)
FTP–8(3–2)
HOT–9(3–3)
O'ALL–9(3–3)
FTP–9(3–3)
0
4
8
12
16
20
24
28
MILES, THOUSANDS

Engine-Out HC and CO



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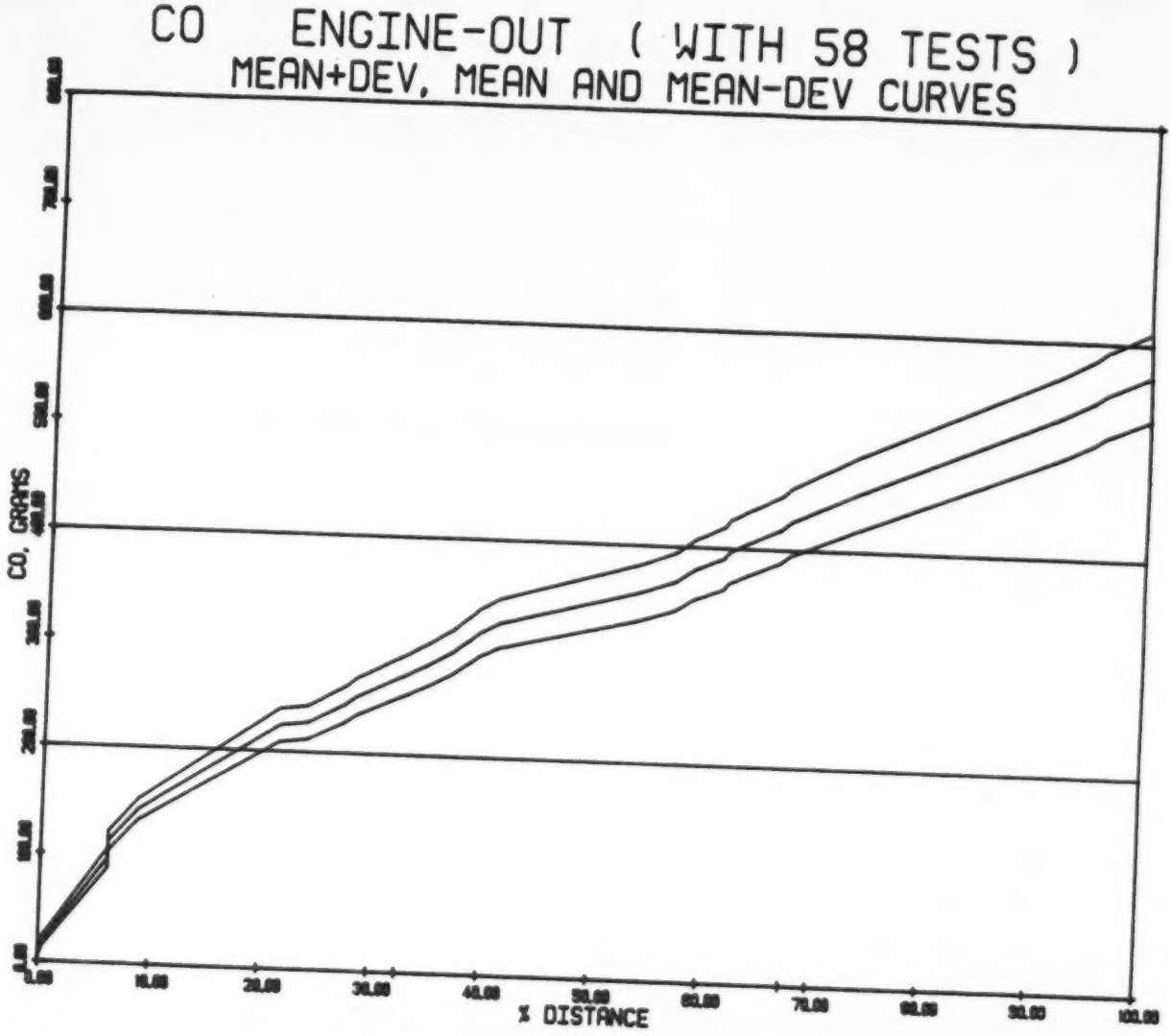
CO ENGINE-OUT (WITH 58 TESTS)
MEAN+DEV, MEAN AND MEAN-DEV CURVES
CO, GRAMS
% DISTANCE

Tabular Summaries of the Data

CATALYST PERFORMANCE DATA FROM AFTERMARKET CATALYST DURABILITY PROGRAM

TEST NO.	CAT #	TEST	MILE	<----HC----> 10% T	50% T	<----CO-----> 10% T	50% T	<--HOT EFF--> HC	CO	<OVERALL EFF> HC	CO	<-FTP EFF-> HC	CO	<- T50* -> HC	CO
2929	1	1	0	43.30	136.34	24.02	47.62	92.04	99.8	84.77	94.87	87.03	96.30	50.1	29.2
2946	1	2	0	40.77	102.84	24.27	51.47	90.23	99.5	83.65	93.66	85.52	95.37	53.1	29.6
2954	2	1	0	30.29	92.98	23.04	36.30	91.39	99.6	86.27	96.37	87.91	97.33	32.1	28.8
2975	2	2	0	28.09	120.69	23.76	54.63	89.09	99.6	82.20	92.38	84.48	94.47	65.2	29.4
2994	3	1	0	43.18	138.75	23.97	45.73	88.18	99.4	82.17	95.20	83.88	96.40	76.8	29.8
3011	3	2	0	74.09	262.47	37.09	99.70	92.96	99.6	77.62	91.01	82.27	93.44	106.2	90.2
3073	4	1	0	82.25	334.31	59.45	211.65	86.49	98.6	73.01	83.68	77.26	87.93	120.1	120.7
3084	4	2	0	62.11	224.82	27.61	123.51	83.22	97.9	74.23	86.84	76.77	89.86	117.1	82.3
3104	5	1	0	59.36	193.78	28.56	107.82	84.70	98.3	76.88	88.59	79.39	91.30	105.3	57.3
3116	5	2	0	54.63	179.88	25.19	78.43	84.12	98.0	77.81	89.59	79.55	91.95	104.9	46.7
3128	6	1	0	69.27	218.77	29.01	144.41	80.04	96.7	72.36	85.36	74.91	88.59	118.1	117.2
3146	6	2	0	81.77	245.25	32.44	166.61	80.60	96.2	70.95	82.83	73.78	86.37	124.1	119.3
3160	7	1	0	43.14	135.85	23.25	41.38	89.70	100.0	81.47	93.20	83.67	94.83	41.9	28.7
3178	7	2	0	42.07	125.95	23.37	55.23	88.03	99.8	79.71	90.06	81.96	92.50	51.0	28.7
3220	8	1	0	44.16	152.77	25.23	81.81	88.56	99.7	80.06	90.62	82.42	92.97	77.5	31.2
3236	8	2	0	45.19	161.14	24.45	55.37	87.62	99.5	79.58	91.64	81.85	93.57	51.5	29.3
3252	9	1	0	42.03	125.89	22.68	36.28	88.92	99.7	82.42	94.54	84.36	95.84	51.5	28.1
3264	9	2	0	47.51	175.39	27.24	70.06	88.91	99.8	79.08	91.50	82.01	93.48	85.0	31.5
3316	2	1	4	26.26	104.73	22.11	41.22	87.21	99.7	79.38	93.57	81.58	95.24	37.8	27.3
3327	2	2	4	45.62	166.99	23.55	38.66	86.68	99.7	79.10	95.66	81.45	96.72	60.2	28.5
3338	3	1	4	46.60	164.93	24.30	58.51	80.77	98.6	75.12	92.78	76.38	94.14	84.6	31.8
3353	3	2	4	44.53	167.04	24.64	62.63	79.66	98.5	73.10	90.12	74.71	92.04	55.1	30.7
3631	5	1	4	135.98	638.78	28.99	218.81	72.53	90.3	60.41	74.21	64.23	78.70	124.0	120.0
3656	5	2	4	128.91	701.61	28.34	269.23	69.33	88.8	56.78	69.59	60.69	74.45	124.2	120.8
3672	6	1	4	85.55	414.53	29.69	212.96	71.40	88.8	61.59	72.98	64.43	76.93	121.5	120.7
3692	6	2	4	71.85	394.84	27.77	173.30	68.60	87.5	60.90	74.98	63.39	78.21	119.8	118.3
3721	8	1	4	44.24	146.01	23.75	49.17	86.53	99.4	78.75	92.38	80.93	94.09	52.4	29.0
3743	8	2	4	43.48	140.19	25.31	66.55	86.61	99.2	77.07	89.94	79.42	92.15	52.5	29.0
3747	9	1	4	48.70	191.33	26.31	96.42	84.58	99.2	73.80	88.01	76.86	90.65	93.8	31.8
3761	9	2	4	92.78	263.33	27.68	108.78	84.46	99.0	72.42	87.27	76.03	90.08	75.5	32.3
3925	2	1	15	46.15	169.21	23.92	49.04	79.47	98.7	74.23	91.46	75.93	93.44	79.3	29.4
3937	2	2	15	43.09	142.87	22.61	46.13	79.50	98.6	75.20	92.52	76.26	94.11	78.4	29.0
3959	3	1	15	81.45	N/A	29.32	N/A	40.44	58.3	34.67	45.61	36.19	48.10	126.8	121.5
3972	3	2	15	127.15	N/A	26.60	748.37	41.72	60.3	34.95	48.28	36.95	50.61	127.2	120.1
4190	5	1	15	133.10	N/A	32.26	599.41	57.99	74.3	47.26	57.60	50.54	61.80	129.8	125.2
4252	5	2	15	143.85	N/A	29.37	649.17	59.16	77.3	48.28	57.89	51.72	62.68	124.7	121.8
0132	8	1	15	59.73	272.03	24.55	122.18	76.72	96.4	65.78	83.11	68.97	86.21	117.4	30.0
0146	8	2	15	84.15	272.51	26.76	184.44	73.95	95.8	64.24	80.18	66.92	83.99	119.1	117.2
0044	9	1	15	46.64	203.87	23.57	85.16	80.06	97.1	69.02	83.34	72.08	86.34	91.5	29.2
0098	9	2	15	69.53	275.30	24.61	146.73	78.84	97.2	67.69	83.07	70.98	86.34	118.0	99.8
3848	1	1	25	59.68	259.17	26.89	104.75	72.00	96.2	64.25	85.32	66.18	87.87	117.2	42.8
3903	1	2	25	53.40	200.98	31.21	76.28	76.27	96.8	67.98	85.82	70.11	88.48	86.4	36.5
4000	1	3	25	51.27	200.91	23.17	47.00	74.59	96.4	67.44	88.13	69.53	89.85	82.1	29.0
0155	2	1	25	40.04	141.06	21.68	34.23	69.12	93.8	66.02	89.31	66.54	90.10	54.5	27.3
0169	2	2	25	43.96	150.58	23.05	43.32	69.85	94.5	66.25	88.25	67.04	89.59	63.7	28.2
0533	3	1	25	79.31	N/A	26.38	N/A	33.18	45.0	28.46	35.09	29.82	37.21	N/A	124.6
0550	3	2	25	94.79	N/A	25.90	N/A	31.95	42.8	26.56	32.88	27.86	34.99	N/A	124.1
0306	4	1	25	120.96	N/A	33.41	1024.96	56.44	72.8	44.23	51.62	47.81	56.68	146.0	125.5
0323	4	2	25	116.56	N/A	27.94	1000.73	55.92	71.8	46.64	53.47	49.34	58.27	155.5	122.1
0636	5	1	25	111.24	N/A	27.53	1012.75	54.89	71.4	45.07	53.27	47.94	57.96	124.4	122.3
0700	5	2	25	73.98	N/A	30.14	1154.60	55.00	69.2	45.72	52.33	48.40	56.87	126.6	123.3
0418	7	1	25	38.30	251.99	25.38	144.85	75.73	95.7	65.89	81.76	67.87	85.08	117.6	31.2
0473	7	2	25	52.31	282.01	35.85	176.42	75.35	97.5	64.74	81.37	67.75	85.25	127.6	42.3
0812	8	1	25	63.44	N/A	24.02	N/A	35.09	31.3	33.77	29.88	34.19	30.17	N/A	126.4
0845	8	2	25	57.66	N/A	38.83	N/A	32.02	32.6	31.35	30.08	31.64	30.89	N/A	N/A
0865	8	3	25	56.34	N/A	32.07	N/A	33.96	34.4	32.76	30.79	33.33	31.88	N/A	N/A
0742	9	1	25	67.32	378.18	35.17	217.76	77.91	96.3	63.52	76.75	67.55	81.39	121.3	119.6
0766	9	2	25	49.96	353.68	32.59	227.61	71.39	94.8	59.59	74.45	62.69	79.37	121.2	119.6

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AVERAGES OF CATALYST PERFORMANCE MEASURES - AFTERMARKET CATALYSTS

CAT #	MILE	<---HC---> 10% T	50% T	<---CO---> 10% T	50% T	<-HOT EFF-> HC	CO	<0'ALL EFF> HC	CO	<-FTP EFF-> HC	CO	<--T50*---> HC	CO
1	0	42.0	119.6	24.1	49.5	91.1	99.6	84.2	94.3	86.3	95.8	51.6	29.4
2	0	29.2	106.8	23.4	45.5	90.2	99.6	84.2	94.4	86.2	95.9	48.6	29.1
3	0	58.6	200.6	30.5	72.7	90.6	99.5	79.9	93.1	83.1	94.9	91.5	60.0
4	0	72.2	279.6	43.5	167.6	84.9	98.3	73.6	85.3	77.0	88.9	118.6	101.5
5	0	57.0	186.8	26.9	93.1	84.4	98.1	77.3	89.1	79.5	91.6	105.1	52.0
6	0	75.5	232.0	30.7	155.5	80.3	96.4	71.7	84.1	74.3	87.5	121.1	118.3
7	0	42.6	130.9	23.3	48.3	88.9	99.9	80.6	91.6	82.8	93.7	46.4	28.7
8	0	44.7	157.0	24.8	68.6	88.1	99.6	79.8	91.1	82.1	93.3	64.5	30.3
9	0	44.8	150.6	25.0	53.2	88.9	99.8	80.8	93.0	83.2	94.7	68.3	29.8
2	4	35.9	135.9	22.8	39.9	86.9	99.7	79.2	94.6	81.5	96.0	49.0	27.9
3	4	45.6	166.0	24.5	56.6	80.2	98.6	74.1	91.4	75.5	93.1	69.9	31.3
5	4	132.4	670.2	28.7	244.0	70.9	89.6	58.6	71.9	62.5	76.6	124.1	120.4
6	4	78.7	404.7	28.7	193.1	70.0	88.1	61.2	74.0	63.9	77.6	120.6	119.5
8	4	43.9	143.1	24.5	57.9	86.6	99.3	77.9	91.2	80.2	93.1	52.4	29.0
9	4	70.7	227.3	27.0	102.6	84.5	99.1	73.1	87.6	76.4	90.4	84.6	32.1
2	15	44.6	156.0	23.3	47.6	79.5	98.6	74.7	92.0	76.1	93.8	78.8	29.2
3	15	104.3	N/A	28.0	748.4	41.1	59.3	34.8	46.9	36.6	49.4	127.0	120.8
5	15	138.5	N/A	30.8	624.3	58.6	75.8	47.8	57.7	51.1	62.2	127.3	123.5
8	15	71.9	272.3	25.7	153.3	75.3	96.1	65.0	81.6	67.9	85.1	118.3	73.6
9	15	58.1	239.6	24.1	115.9	79.4	97.1	68.4	83.2	71.5	86.3	104.8	64.5
1	25	54.8	220.4	27.1	76.0	74.3	96.5	66.6	86.4	68.6	88.7	95.2	36.1
2	25	42.0	145.8	22.4	38.8	69.5	94.1	66.1	88.8	66.8	89.8	59.1	27.8
3	25	87.0	N/A	26.1	N/A	32.6	43.9	27.5	34.0	28.8	36.1	N/A	124.4
4	25	118.8	N/A	30.7	1012.8	56.2	72.3	45.4	52.5	48.6	57.5	150.8	123.8
5	25	92.6	N/A	28.8	1083.7	54.9	70.3	45.4	52.8	48.2	57.4	125.5	122.8
7	25	45.3	267.0	30.6	160.6	75.5	96.6	65.3	81.6	67.8	85.2	122.6	36.8
8	25	59.1	N/A	31.6	N/A	33.7	32.8	32.6	30.3	33.1	31.0	N/A	126.4
9	25	58.6	365.9	33.9	222.7	74.6	95.6	61.6	75.6	65.1	80.4	121.3	119.4

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